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TRANSACTIONS

OF THE

AMERICAN INSTITUTE OF MINING ENGINEERS.

VOL. XXIX.

FEBRUARY, 1899, TO SEPTEMBER, 1899.

INCLUSIVE.

NEW YORK CITY:

PUBLISHED BY THE INSTITUTE,

AT THE OFFICE OF THE SECRETARY.

1900.

PREFACE.

The statement, made in the Preface to Vol. XXVIII., of the conditions and difficulties attending the publication of these *Transactions*, might well be repeated with each new volume. Indeed, the steady growth of the Institute in membership, and the increased number of contributions from members in distant lands, add every year to the labor and time required for the production of a volume approximately free from errors of the pen or press. Inasmuch as the preliminary pamphlet edition furnishes copies of all papers for immediate use, the date of issue of the permanent volumes is subordinate in importance to their perfected accuracy, with regard to which, I venture to believe that the present volume maintains the high standard set by its predecessors.

In this connection, I would here acknowledge the efficient assistance of Prof. W. H. Pettee, of the University of Michigan, who has, for many years past, given to the sheets of the volume of *Transactions* their final revision. The importance of such a minute supplemental scrutiny is shown by the fact that, of several thousand papers thus submitted to Prof. Pettee, probably less than a score have escaped without some minute correction.

For the present volume, I have to acknowledge also the great service rendered by Mr. Benjamin Smith Lyman, of Philadelphia, who has revised with care the discussion of Mr. Scott's paper in Vol. XXVIII. on "The Evolution of Mine-Surveying Instruments." This discussion, in which many experts of other countries have taken part, will be continued in the next volume.

R. W. Raymond.

New York, July, 1900.

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OFFICERS.

For year ending February, 1900.[1]

President.

JAMES DOUGLAS, LL.D., New York City.

Vice-Presidents.

E. D. PETERS, JR.,	Dorchester, Mass.
ALBERT R. LEDOUX,	New York City.
LEON P. FEUSTMAN,	Mexico City, Mexico.

(Term expires February, 1900.)

E. C. POTTER,	Chicago, Ill.
GEORGE F. KUNZ,	New York City.
W. N. PAGE,	Ansted, W. Va.

(Term expires February, 1901.)

Managers.

C. W. GOODALE,	Butte, Mont.
FRANK LYMAN,	Brooklyn, N. Y.
FRANK McM. STANTON,	Houghton, Mich.

(Term expires February, 1900.)

R. P. ROTHWELL,	New York City.
W. J. OLCOTT,	Duluth, Minn.
W. B. DEVEREUX,	Glenwood Springs, Colo.

(Term expires February, 1901.)

ARTHUR WINSLOW,	St. Louis, Mo.
WILLIAM GLENN,	Baltimore, Md.
W. J. TAYLOR,	Bound Brook, N. J.

(Term expires February, 1902.)

Secretary.

R. W. RAYMOND,
99 John St., New York City.

Treasurer.

THEODORE D. RAND,
Philadelphia, Pa.

Honorary Members.

PROF. RICHARD ÅKERMAN, Stockholm, Sweden; SIR LOWTHIAN BELL, Middlesborough, England; DR. THOMAS M. DROWN, South Bethlehem, Pa.; PROF. HATON DE LA GOUPILLIÈRE, Paris, France; PROF. HANS HOEFER, Leoben, Austria; DR. BRUNO KERL, Berlin, Germany; PROF. JOSEPH LE CONTE, Berkeley, Cal.; PROF. J. P. LESLEY, Philadelphia, Pa.; M. FLORIS OSMOND, Paris, France; PROF. SIR WILLIAM C. ROBERTS-AUSTEN, London, Eng.; PROF. DR. HERMANN WEDDING, Berlin, Germany.

[1] The following officers were elected at the Annual Meeting, February, 1900. *President*, James Douglas, New York City; *Vice-Presidents* (to serve two years), David T. Day, Washington, D. C.; J. B. Randol, New York City; W. C. Ralston, San Francisco, Cal.; *Managers* (to serve three years), D. H. Bacon, Soudan, Minn.; E. V. D'Invilliers, Philadelphia, Pa.; William Kent, Passaic, N. J.; *Treasurer*, Theodore D. Rand, Philadelphia, Pa.; *Secretary*, Rossiter W. Raymond, New York City.

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* Annual meeting for the election of officers. The rules were amended at the Chattanooga meeting, May, 1878, changing the annual election from May to February.

† Begun in May at Easton, Pa., for the election of officers, and adjourned to Philadelphia.

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* Annual meeting for the election of officers.
† Begun in February at New York City, for the election of officers, and adjourned to Florida.

PUBLICATIONS.

THE publications of the Institute comprise:

PAMPHLETS.

1. The minutes of the Proceedings of each Meeting.

2. Such of the papers presented or read by title at each Meeting as are furnished by the authors and approved by the Council for full publication. (In nearly all cases in which papers, the titles of which appear in the Proceedings, are not subsequently published, they have been withdrawn by the authors.) These papers are published separately in pamphlet form, and are marked "subject to revision." Beyond the edition distributed without charge to members and associates not in arrears, a small supply is retained to meet subsequent demand. There are no copies on hand of papers read before 1880. The stock is nearly complete from 1880. These papers are for sale at the office of the Secretary, or are sent to purchasers by mail or express, charges paid, on receipt of the price, as follows:

No. of Pages.	Single Copies.	10 Copies.	20 Copies.
8 or less	$0 06	$0 30	$0 50
9 to 12 inclusive	0 08	0 60	1 00
13 to 16 "	0 12	1 00	1 75
17 to 20 "	0 16	1 25	2 25
21 to 24 "	0 20	1 50	2 75
25 to 40 "	0 25	2 00	3 50
41 to 56 "	0 30	2 50	4 50
57 to 72 "	0 35	3 00	5 00
73 to 88 "	0 40	3 25	5 25
89 to 104 "	0 45	3 50	6 00
105 to 120 "	0 50	3 75	6 25

Papers with folders and inserted plates subject to special price.

TRANSACTIONS.

The volumes of *Transactions*, which are published annually, contain the list of officers, rules, etc., the Proceedings, and the papers revised for final publication. (In this revision, after the preliminary publication, authors are permitted to use the largest liberty; and the changes and additions made in papers are sometimes important. It should be borne in mind, by those who study or quote a paper in the preliminary edition, that they may not have in that form the ultimate and deliberate expression of the author's views. It should be added, however, that in the majority of cases there is no important change.) Those volumes are for sale as follows, in paper covers:

Vols. I. to IV., inclusive, each, ...	$3 00
Vols. V. to VIII., inclusive, each, ...	4 00
Vols. IX. and X. (a small supply only on hand), . .	10 00
Vols. XI. to XXVII., inclusive, each, ...	5 00

Half-morocco binding, $1 extra per volume.

Indexes and Special Editions.

Index, Vols. I. to XV., inclusive, of the *Transactions*, cloth, .	$1 00
Index, Vols. XVI. to XX., inclusive, paper, ...	1 00
Index, Vols. XXI. to XXV., inclusive, cloth, ...	1 25
Indexes, Vols. I. to XV. and XVI. to XX., bound in one volume, cloth, ...	2 00
Indexes, Vols. I. to XV., XVI. to XX., and XXI. to XXV., bound in one volume, cloth, ...	3 00
Geological Map of the United States, colored after the scale proposed by the International Geological Congress, by Prof. C. H. Hitchcock, ...	1 00
Memorial of Alexander L. Holley, with portrait, cloth, .	1 00
List of Members, Rules, etc., paper, ...	25

Authors' Editions of Pamphlets.

Extra copies, when ordered before the types have been distributed, are furnished to authors, under Rule VII., at the following rates:

No. of Pages.	50 Copies.	100 Copies.	250 Copies.	Each additional 100 copies above 250.
4 or less	$1 25	$1 50	$2 25	$0 50
5 to 8 inclusive	1 75	2 25	3 25	0 75
9 to 12 "	2 25	3 00	4 25	1 00
13 to 16 "	2 75	3 75	5 25	1 25
17 to 20 "	3 25	4 50	6 25	1 50
21 to 24 "	3 75	5 25	7 25	1 75
25 to 28 "	4 25	6 00	8 25	2 00
29 to 32 "	4 75	6 75	9 25	2 25
Covers (including printing on first page of the same), extra	1 50	2 00	3 00	0 50

Papers with folders and inserted plates subject to special price.

All communications and remittances should be addressed to R. W. Raymond, Secretary, P. O. Box 223, New York City.

RULES

ADOPTED MAY, 1873. AMENDED MAY, 1875, 1877, AND 1878, FEBRUARY, 1880, 1881, 1887, 1890, AND 1896.

I.

OBJECTS.

THE objects of the AMERICAN INSTITUTE OF MINING ENGINEERS are to promote the arts and sciences connected with the economical production of the useful minerals and metals, and the welfare of those employed in these industries, by means of meetings for social intercourse, and the reading and discussion of professional papers, and to circulate, by means of publications among its members and associates, the information thus obtained.

II.

MEMBERSHIP.

The Institute shall consist of Members, Honorary Members, and Associates. Members and Honorary Members shall be professional mining engineers, geologists, metallurgists, or chemists, or persons practically engaged in mining, metallurgy, or metallurgical engineering. Associates shall include all suitable persons desirous of being connected with the Institute, and duly elected as hereinafter provided. Each person desirous of becoming a member or associate shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting (or by ballot at any time conducted through the mail, as the Council may prescribe) upon receiving three-fourths of the votes cast, and shall become a member or associate on the payment of his first dues. Each person proposed as an honorary member shall be recommended by at least ten members or associates, approved by the Council, and elected by ballot at a regular meeting (or by ballot at any time conducted through the mail, as the Council may prescribe) on receiving nine-tenths of the votes cast; *Provided*, that the number of honorary members shall not exceed twenty. The Council may at any time change the classification of a person elected as associate, so as to make him a member, or *vice versa*, subject to the approval of the Institute. All members and associates shall be equally entitled to the privileges of membership; *Provided*, that honorary members shall not be entitled to vote, and members or associates whose post-office address shall be outside of the United States, Canada and Mexico shall not be entitled to vote by mail, except upon proposed amendments to the Rules.

Any member or associate may be stricken from the list on recommendation of the Council, by the vote of three-fourths of the members and associates present at any annual meeting, due notice having been mailed in writing by the Secretary to the said member or associate.

III.

DUES.

The dues of members and associates shall be ten dollars, payable upon their election, and ten dollars per annum thereafter, payable in advance on the first day of each calendar year. Honorary members shall not be liable to dues. Any member or associate not in arrears may become by the payment of one hundred dollars at one time a life-member or associate, and shall not be liable thereafter to annual dues. Any member or associate in arrears may, at the discretion of the Council, be deprived of the receipt of publications, or stricken from the list of members when in arrears for one year; *Provided*, that he may be restored to membership by the Council on payment of all arrears, or by re-election after an interval of three years.

IV.

OFFICERS.

The affairs of the Institute shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, a Secretary and a Treasurer, who shall be elected from among the members and associates of the Institute at the annual meetings, to hold office as follows:

The President, the Secretary, and the Treasurer for one year (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of these rules, for two consecutive years), the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. At each annual meeting a President, three Vice-Presidents, three Managers, a Secretary, and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the Council or the Institute; and the Council may in its discretion require bonds to be given by the Treasurer. At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Vacancies in the Council may occur by death or resignation; or the Council may, by a vote of the majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meetings or perform the duties of his office. All vacancies shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; *Provided*, that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to

the approval of a majority of the Council, subsequently given in writing to the Secretary, and recorded by him with the minutes.

V.

ELECTIONS.

The annual election shall be conducted as follows: Nominations may be sent in writing to the Secretary, accompanied with the names of the proposers, at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before the said meeting, mail to every member or associate (except honorary members) a list of all the nominations for each office so received, together with a copy of this rule, and the names of the persons ineligible for election to each office; and if the Council, or a Committee thereof, appointed for the purpose, shall have recommended any nominations, such recommendation may also be sent to members and associates with the said list of all nominations made, but not upon the same paper. And each member or associate, qualified to vote, may vote, either by striking from or adding to the names of the said list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing said altered or prepared ballot with his name, and either mailing it to the Secretary or presenting it in person at the annual meeting; *Provided*, that no member or associate in arrears since the last annual meeting shall be allowed to vote until the said arrears shall have been paid. The ballots shall be received and examined by three Scrutineers, appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected, and the Scrutineers shall so report to the presiding officer. The ballots shall be destroyed, and a list of the elected officers, certified by the Scrutineers, shall be preserved by the Secretary.

VI.

MEETINGS.

The annual meeting of the Institute shall take place on the third Tuesday of February, at which a report of the proceedings of the Institute and an abstract of the accounts shall be furnished by the Council. Other meetings shall be held in each year, at such times and places as the Council shall select, and notice of all meetings shall be given by mail, or otherwise, to all members and associates, at least twenty days in advance.

Every question which shall come before any meeting of the Institute, shall be decided, unless otherwise provided by these Rules, by the votes of a majority of the members then present. Any member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

VII.

PAPERS AND PUBLICATIONS.

The Council shall have power to decide on the propriety of communicating to the Institute any papers which may be received, and they shall be at liberty, when they think it desirable, to direct that any paper read before the Institute shall

be printed in the *Transactions*. Intimation, when practical, shall be given, at each general meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting. The reading of papers shall not be delayed beyond such hour as the presiding officer shall think proper; and the election of members or other business may be adjourned by the presiding officer, to permit the reading and discussion of papers. The published papers and volumes of *Transactions* shall be distributed to all members and associates not in arrears, and may be sold to the public upon such conditions as the Council shall prescribe; but the Council may, in its discretion, omit sending to members and associates outside of the United States, Canada and Mexico, special circulars, unless the same contain proposed amendments to the Rules.

The copyright of all papers communicated to, and accepted by, the Institute, shall be vested in it, unless otherwise agreed between the Council and the author. The author of each paper read before the Institute shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing, provided said copies are not intended for sale. The Institute is not, as a body, responsible for the statements of fact or opinion advanced in papers or discussions at its meetings, and it is understood that papers and discussions should not include matters relating to politics or purely to trade; nor shall the Council or the Institute officially approve or disapprove any technical or scientific opinion or any proposed enterprise outside the management of the meetings, discussions and publications of the Institute, as provided in these Rules; *Provided*, however, that committees may be appointed by the Council or the Institute to make investigations and submit reports at meetings of the Institute; but no action shall be taken binding the Institute for or against the conclusions of any such reports.

VIII.

AMENDMENTS.

These Rules may be amended at any annual meeting by a two-thirds vote of the members present; *Provided*, that written notice of the proposed amendment shall have been given at a previous meeting; *and Provided, also*, that the amendment or amendments so adopted shall be printed upon a ballot and sent, not later than the next distribution of printed matter, to all members and associates not in arrears for the preceding year (except honorary members and foreign members elected before February, 1880), and each person receiving the same shall be requested to return it to the Secretary with his written vote of Yes or No to each amendment, and his signature; and the President shall appoint as Scrutineers three members or associates, who shall examine all of the said ballots which shall have been returned within one month from the date of their distribution, and shall report the result; and the Secretary shall publish and distribute to members, not later than the next distribution of printed matter, an announcement of the said result so reported, together with the text of the additional or amended rule or rules so adopted; and the amendment or amendments approved by the majority of the ballots so returned and reported shall become part of these Rules from and after the publication of said announcement by the Secretary.

Proceedings of the Seventy-Sixth (Twenty-Ninth Annual) Meeting, New York City, February, 1899.

Committees.

General Committee.—Edward Cooper, W. S. de Camp, August Heckscher, A. C. Humphreys, D. S. Jacobus, G. F. Kunz, A. R. Ledoux, H. S. Munroe, De Veaux Powel, R. P. Rothwell, E. G. Spilsbury, Frank S. Witherbee, A. Eilers, Henry S. Drinker, L. Holbrook, C. W. Hunt, J. F. Kemp, J. Langeloth, Frank Lyman, A. L. Norrie, J. B. Randol, A. J. Rossi, W. H. Wiley, J A. Walker.

Reception Committee.—Charles Kirchhoff, Abram S. Hewitt, H. M. Howe, James Douglas, Andrew Carnegie, Thomas Robins, Jr., L. W. Francis. R. W. Raymond, William E. Dodge, W. A. Clark, W. B. Kunhardt, Theodore Dwight.

Excursion Committee.—E. E. Olcott, H. A. J. Wilkens, James B. Tonking, James Douglas, William P. Hardenbergh, Joseph A. Van Mater.

Hotel Headquarters.—The Murray Hill Hotel, 40th street and Park avenue.

The opening session was held on Tuesday evening, February 21st, at the Hall of the American Society of Mechanical Engineers (generously placed at the service of the Institute by the Council of that Society). President Kirchhoff called the meeting to order, and in his capacity as Chairman of the Reception Committee, welcomed the visiting members.

Messrs. G. W. Maynard, Howard Van F. Furman and E. W. Parker were appointed Scrutineers to examine the ballots received by mail, and to report the result at a later session.

The Secretary announced that the Council had decided to hold the next meeting of the Institute in San Francisco, accepting the earnest invitation to that effect tendered by the California Miners' Association. The meeting will probably take place early in October; and a preliminary circular stating the proposed arrangements and probable expense of the trip will be issued in due time from the Secretary's office. It was also announced that the Canadian Mining Institute will hold a meeting next autumn in British Columbia—the party from the East leaving Montreal about September 1st, and spending the greater part of that month in visiting the important mining districts and scenic attractions of that Province. Members of the Institute are cordially invited to join this party; and those

who have time and desire to do so could afterwards join the Institute at San Francisco, and take part in its California meeting, thus acquiring in two months a personal knowledge of the mining and metallurgical industries and the magnificent scenery of the Pacific coast, not otherwise to be gained in that period, even at much greater expense.

A Biographical Notice of the late Oberberghauptmann Dr. Albert L. Serlo, Honorary Member of the Institute, written by Prof. Dr. Hermann Wedding, Berlin, Germany, and translated by the Secretary, was then read.

Mr. James Douglas, New York City, presented a paper on the "Copper Queen Mine, Arizona," illustrated with lantern-slides.

Mr. E. E. Olcott, New York City, exhibited an interesting series of lantern-pictures illustrative of Peruvian gold-fields and their primitive exploitation by the natives, as seen by him in a recent exploration of the placer-deposits of that country.

The session was then adjourned, and a social reception followed.

The second session was held in the Havemeyer Hall of Columbia University. Prof. H. S. Munroe, Dean of the Faculty of the School of Mines, welcomed the Institute in the following interesting address:

The absence of President Low in Philadelphia throws upon me the pleasant duty of welcoming you as our guests in the new home of the University. The Institute of Mining Engineers and the Columbia School of Mines need no introduction. It is rather as old friends, whom we are heartily glad to see again, that we greet you to-day. When a man builds a new house he expects his friends to enjoy it with him, and to take the same interest in it that he does. He delights to show them over it from cellar to attic, that they may admire it in detail, its rooms and halls, its plumbing, closets, bay-windows, mantels, corner-cupboards and wall paper. So we shall give you an opportunity to see our new buildings at the end of this session and after luncheon. In anticipation of this inspection of our new buildings, permit me to bring to your notice these illustrated pamphlets, with covers printed in the college color, containing elevations and floor plan of the different buildings which will serve as guide-books.

The large library building, as most of you know, is a gift of President Low as a memorial to his father. It is planned to contain a million and a half of books (a number about six times as large as we now have), which we shall probably not reach until toward the end of the next century. In the meantime, until this building shall be wholly needed for books, it is temporarily occupied by some of the offices of the University, and on the upper floors by some of the graduate faculties, such as those of law, philosophy, and political science. There are

lecture-rooms on the upper floors of the library building capable of accommodating a thousand pupils at one time. Aside from this temporary use, the large library building is really planned as a great laboratory for those whose chief work is research, and who have to refer to books as the means of that research. In addition to the large reading-room there are smaller reading-rooms; one for the law-students, where the law-library is installed; and another in the east wing, connecting the Avery Architectural Library, containing some 16,000 volumes of architectural and archæological books. Then on the upper floors there are some eighteen smaller reading-rooms, with alcoves, for advanced students, in which they can read in close proximity to the shelves, using the books they need. These can be thrown into one large lecture-room, or into two or three or more smaller rooms. The whole library is planned so as to facilitate the use of books as far as practicable.

Fayerweather Hall, or the Physics Building, which was erected from the Fayerweather bequest, accommodates the departments of physics, mechanics, astronomy, and (temporarily) English literature and rhetoric. This building is the easternmost of the group of four large buildings on Amsterdam avenue. Next to this is Schermerhorn Hall, a large building accommodating the departments of natural science and natural history; that is to say, of geology, palæontology, mineralogy, botany, zoology and psychology, with their necessary museums, laboratories and lecture-rooms.

This building in which this session is held is Havemeyer Hall, the gift of the Havemeyer family in memory of their father, which contains the chemical laboratories, and accommodates (temporarily) the department of metallurgy on the lower floors and the department of architecture on the upper floors.

Finally, the fourth of the group of academic buildings is the engineering building, which still awaits a donor and a name. It accommodates the departments of mining, civil, electrical and mechanical engineering.

The unfinished building back of the library contains the boiler-house and power-plant of the University and the gymnasium. In front of Havemeyer Hall, and between it and the engineering building, is a great underground vault over 200 feet long, 35 feet wide and 25 feet high, which is now utilized as the mechanical laboratory of the University. It contains the hydraulic laboratory given by Mr. C. C. Worthington, in memory of his distinguished father, Henry R. Worthington; a 150 horse-power triple-expansion Allis-Corliss engine, a memorial to the great Edward P. Allis, of Milwaukee; and also the Baldwin compound locomotive "Columbia," which was exhibited at the Columbian Exposition in Chicago, and which has very appropriately come to this University as its final resting-place.

West Hall, the building in front of us, which was formerly one wing of the Bloomingdale Asylum, contains the lunch-rooms, and also accommodates the departments of history and modern languages.

Finally, there is College Hall, a small brick building on the corner of Amsterdam avenue and 116th street, which houses the departments of mathematics, Latin and Greek.

It is important to note that of the six new buildings four are devoted to science —an interesting commentary on the part which science plays in modern education. Another fact deserving of mention is that the new buildings are of fire-proof construction throughout, and so solidly and honestly constructed that they should be as serviceable a century hence as they are to-day. These two statements can probably not be made with regard to any other group of college buildings in the United States.

An additional interesting feature is, that the plans for the buildings and the arrangement of the grounds were begun in 1892, while the corner-stones were not laid until 1896; so that about four years were spent in studying and planning the arrangements of these buildings before they were actually constructed. Moreover, the first plans were made by the faculty, and the architectural studies were subject to our criticism from first to last. The result is that the buildings are admirably adapted to our work in every detail. This is in striking contrast to the experience of the professors of one of the largest universities of Europe. When I visited their new building in 1892, the professor of chemistry took me into the wing which had been assigned to him for his laboratory. There was no water, no gas, no plumbing, no flues, and no way of providing for these necessary adjuncts except by tearing the building to pieces or by employing miserable makeshifts, as, in many cases, he had been obliged to do.

Our new buildings contain about fifty lecture-rooms, capable of seating at one time about 4000 students; and seventy laboratories, capable of giving accommodation for the work at one time of nearly 2000 men. The total value of the plant of Columbia University to day, including the medical school on 59th street, is probably somewhere in the neighborhood of eight million dollars. The productive endowment-fund is something like ten million dollars, with about two million dollars more in sight. It is planned to erect eventually on this place, as the necessity shall arise, twenty-one buildings, which will accommodate at least 8000 or 10,000 students, and probably many more. The buildings already erected are quite sufficient for our present needs; but it should be added that we have as many, or nearly as many, students as we can take care of with our present endowment. The income from the total endowment-fund of, say, ten million dollars, is approximately $400,000 a year. The fees which we receive from the students now here amount, approximately, to $350,000. The gifts which have been received in the past for current expenses amount to about $25,000 annually, and the deficit, on educational expenses alone, has been something like $30,000. Hence, even with our large endowment, we can only take care of the present number of students. When the number shall have increased to 8000 or 10,000, we shall probably need some fifty or sixty million dollars to carry on this work. This, however, need not worry us at present. It is a matter for the future. It is more than probable that the assistance needed will be forthcoming during the next century. We feel that we have got to keep up to our needs; and we look hopefully to the wealth and public spirit of New York to support the University on a worthy scale.

This hope is justified by experience. During the last seven years the gifts to Columbia have been upwards of six million dollars. We do not by any means need to maintain that rate of addition to our fund in order to keep abreast with the growth of the institution. At present, owing to the fact that we are a little ahead of time in the number of students, and that we have the temporary annual deficit already mentioned, we have to "mark time," as it were, and wait until our income grows a little before we can accommodate as many more students as we should like. This period of marking time, we hope, will not be long; and it certainly is a small price to pay for the advantages that we have gained by moving the University to the new site. Our growth in the past few years has been phenomenal. Some departments have increased nearly 50 per cent.; and it was this great and rapid growth that made necessary the new site and the new buildings. On the old site we had cramped and inadequate quarters, and we found it impossible to grow; but the lessons that were learned there have been utilized in the design and arrangement of this new plant, and in laying out the ground.

The work has been done for all time; and the temporary pause which we are just now experiencing will not, we believe, long interrupt our steady progress.

Mr. Kirchhoff then delivered the Presidential Address, on "A Decade of Progress in Reducing Costs."*

A paper on "The Equipment of Metallurgical Laboratories" was read by Prof. H. M. Howe, Columbia University, after which the session was adjourned to permit the members and guests to inspect the buildings of the University.

The third session was held in the same place on Wednesday afternoon, February 22d.

Prof. J. F. Kemp, Columbia University, gave, by request, an informal account, illustrated with lantern-slides, of the New Jersey zinc-mines, which were to be visited by the Institute on February 24th.†

The session was closed with the reading of a paper by Robert H. Chapman, U. S. Geological Survey, on "The Geological Structure of the Rocky Mountains within the Lewis and Clarke Timber Reserve, in Montana."

Before adjournment the Secretary repeated the announcement made at previous sessions, that many papers‡ (including some from the Buffalo meeting) were on hand in printed form in numbers sufficient to supply all applicants; and that any one of them, or any other paper of a former meeting, would be called up for discussion upon notice of a desire to that effect from any member. Otherwise, the time of the Institute would not be occupied by the reading of papers, already in print, which no one present had signified a desire to discuss.

The Secretary announced, also, that no new members would be elected at this meeting whose names had not been already sent out by circular to members generally. Candidates proposed since the issue of last circular would be considered by the Council later. But all candidates duly proposed and sec-

* See p. 352.

† This will not be published. A summary account of these mines and works, prepared by Mr. H. A. J. Wilkens, will be found below under the head of "Excursions." For further information, see the paper of Mr. Frank L. Nason, on "The Franklinite Deposits of Mine Hill, N. J.," *Trans.*, xxiv., 121.

‡ See list, p. xxxviii.

onded according to the Rules were cordially invited to participate as guests in the proceedings and entertainments of this meeting.

The fourth session was held on Thursday morning, February 23d, at the Hall of the American Society of Mechanical Engineers.

The paper of Dr. Persifor Frazer, on "The Kytchtym Medal," presented at the Buffalo meeting, October, 1898, was further discussed.

The following papers were presented by the authors:

"The Coking in Beehive Ovens of the Coals of the New River District, West Virginia," by Charles Catlett, Staunton, Va.

"Important Results Obtained in the Past Fifteen Years with Stiff and Heavy Rail-Sections," by P. H. Dudley, New York City.

The Secretary made a statement of interesting discussion received by mail from expert authorities in this and other countries, upon the subject of Mr. Dunbar D. Scott's paper on "The Evolution of Mine-Surveying Instruments" (Buffalo meeting), and, there being no members present who desired to continue the subject orally, invited further discussion by mail, to be printed and distributed to members, together with that already received, and announced that Messrs. C. L. Berger & Sons, of Boston, who manufacture Mr. Scott's "tachymeter," had kindly provided an exhibit of mine-surveying instruments, including this one, which would be shown and explained after the session; also that Messrs. Keuffel and Esser, of New York, had furnished, and would similarly exhibit to those interested, instruments of their manufacture.

In the absence of the author, the Secretary presented, with a summary statement of its nature and contents, the paper of Mr. Clemens C. Jones, Richmond, Va., on "A Geologic and Economic Survey of the Clay-Deposits of the Lower Hudson River Valley," and gave, also, a brief statement of the substance of other papers presented in print but not called up for discussion.*

* See list, p. xxxviii.

The fifth and final session was held at the same place on Thursday evening, February 23d.

Mr. E. W. Parker, U. S. Geol. Survey, presented a paper, illustrated with lantern-slides, on "Coal-Cutting Machinery."

The annual report of the Council was presented as follows:

Annual Report of the Council.

In accordance with the rules, the Council makes the following report to the Institute:

The financial statement of the Secretary and Treasurer shows receipts from all sources for the year ending December 31 (including $2,965.65 on hand at the beginning of the year) of $32,513.97, and expenditures of $24,904.91, leaving a surplus of $7,609.06, a gain upon the surplus of January 1, 1898, of $4,643.41, of which $2,509.02 is due to payments for life-membership, leaving $2,134.39 as the net excess of current receipts over current expenditures. In addition to the cash balance the Treasurer holds United States bonds of the par value of $2900, and other securities of the par value of $9000; the total market-value of these investments being a little over $15,000, and the total annual revenue from securities and deposits being a little over $800. The invested fund, however, still falls short of the amount of $100 for each life-member, and further investments will be made from time to time for this purpose.

This favorable financial showing will permit the Council to incur the relatively small additional expense of a step which has long been desirable, namely, the removal of the Secretary's office to more convenient quarters in a fire-proof building, thereby securing the safety of the valuable pamphlets, exchanges and volumes now possessed by the Institute. No money-value has been placed upon these publications as an asset of the Institute; but it is only fair to say that the pamphlets and back-volumes of the *Transactions* on hand, reckoned at the price at which they find a steady small sale, realizing over $1000 per annum, would represent over $50,000, of which, say $5000 worth, is kept at the Secretary's office to meet current demands, and the remainder is stored in a fire-proof warehouse.

The detailed statement of receipts and expenditures is as follows:

RECEIPTS.

Balance from statement, ...		$ 2,965.65
Annual dues, ...	$22,608.16	
Life membership, ...	2,509.02	
Binding of *Transactions*, ...	1,915.18	
Sale of publications, ...	1,674.51	
Electrotypes, ...	9.80	
Interest on bonds and deposits, ...	831.65	29,548.32
		$32,513.97

DISBURSEMENTS.

Printing Volume xxvii. of *Transactions*, . . .	$3,076.89	
" pamphlet edition of papers, ...	2,154.25	
" mailing list, ...	20.80	
" circulars and ballots, ...	121.31	
Binding Volume xxvii. and miscellaneous volumes of *Transactions*, ...	1,765.23	
Binding exchanges, ...	80.76	
Engraving and electrotyping, ...	1,268.57	
Secretary's department, including clerks, stenographers and expenses of editing and proof-reading, ...	8,160.00	
Postage, including post-office box rent, . . .	1,353.99	
Stationery, ...	288.33	
Rent, ...	800.00	
Express and freight charges, ...	1,117.26	
Telephone, ...	155.40	
Telegrams, cablegrams and car-fare, ...	22.32	
Coal, ice and gas, ...	80.54	
Assistant Treasurer's department, ...	3,037.75	
Storage of *Transactions*, ...	105.21	
Special stenographers and expenses of meeting, .	822.14	
Office supplies and repairs, ...	422.61	
Insurance, ...	24.50	
Miscellaneous, ...	27.05	
		$24,904.91
Balance, ...		7,609.06
		$32,513.97

Two meetings were held during the year, the annual meeting in February at Atlantic City, N. J., and a meeting at Buffalo, N. Y., in October. The *Transactions* bear evidence of the professional importance of these meetings, and their social success is a delightful memory to all who participated in the sessions, entertainments, excursions and friendly intercourse connected with them.

Changes in membership have taken place during the year as

follows: 184 members and 23 associates have been elected; 10 associates have become members; the deaths of 2 honorary members, 25 members and 2 associates have been reported; 47 members and 5 associates have resigned. These changes are tabulated as follows, showing a net gain of 76 in total membership:

	H. M.	F. M.	M.	A.	Totals.
At date of last report	11	37	2276	174	2498
Gains: By Election	....	....	184	23	207
Change of Status	....	....	10	....	10
Losses: By Resignation	....	....	47	5	52
Dropping	....	....	42	8	50
Change of Status	....	....	....	10	10
[illegible]	2	....	25	2	29
Total gains	....	....	194	23	217
Total losses	2	....	114	25	141
Present membership	9	37	2356	172	2574

The list of deaths reported during the past year comprises the following: *Honorary Members:* Theodor Richter, Albert Serlo; *Life Members:* Joseph C. Platt, John Gray Torrey; *Members and Associates:* John F. Armstrong (1890), William Ayers (1897), Edgar H. Booth (1892), J. H. Carpenter (1891), W. H. Case (1878), J. W. Chalfant (1873), Thomas S. Disston (1886), Charles E. Emery (1880), T. E. Fuller (1898), William Kennedy Gibson (1894), J. B. Goodwillie (1897), Thomas Hoatson (1880), James P. Hosic (1889), M. P. Janney (1874), Edward C. Koch (1897), S. W. McKeown (1883), Fred. P. Miles (1877), W. S. Rosecrans (1876), Edwin E. Sluder (1883), W. T. Smith (1887), Alexander Thielen (1891), A. S. Van Wickle (1888), Thomas J. Waters (1886), Rowland Hazard (1887), and Archibald Means (1882).*

Of these, Richter and Serlo have been suitably commemorated in special biographical notices. Concerning the others, such data as have been obtained by the Secretary are given below, in the alphabetical order of their names.

John F. Armstrong was born in Canada, and went to Marquette, Mich., with his parents and brothers and sisters about 1874. He occupied successively positions at the Boston mine,

* The date in parenthesis is that of election as member or associate.

the mines of the Cleveland Co. at Ishpeming (where he rose to be Assistant Superintendent); the Fitch mine, Marquette county; the Hemlock mine, on the Menominee range; the Canton mine and the Sellers mine, on the Mesabi range. He was also employed for a short period in Idaho. He enjoyed a high reputation for honesty, industry and careful attention to his duties as a mine manager. Mr. Armstrong became a member of the Institute in 1890.

William Ayers began his mining experience in 1884 in Southern Arizona, in charge of a mine owned by a Philadelphia company. A year later he traveled with a single companion across the country, during an Apache outbreak, encountering some exciting experiences on the way to the San Juan regions in Colorado, in which State, chiefly around Ouray and Boulder, he was exploring and mining for several years; then going, on account of his health, to take charge of a mine near Socorro, N. M., and still later to San Juan, Arizona. After 1890 he was engaged in examining and reporting for New England parties, chiefly upon mining properties in various parts of North America, from Nova Scotia to California; and his work ended, as it had begun, in Arizona. He was esteemed and trusted for his good judgment and integrity. Mr. Ayers did not become a member of the Institute until 1897, and his death in the following year deprived us of the fruits of his experience.

William H. Case, who died in Brooklyn, October 24, 1898, was born in Columbia county, N. Y., and graduated in 1867 as a civil engineer at Union College, Schenectady, N. Y. After some years, spent largely in railroad work, he opened at Port Henry, N. Y., in 1873, a general engineering office, and became connected with the large iron-mines of that locality, in the exploitation of which he successfully introduced a new system, securing both greater economy and greater safety. In 1878 he became a member of the Institute. From 1883 to 1888 he was superintendent of the Mahopac Iron Ore Co.'s mines, at Lake Mahopac, N. Y., resigning his position in the latter year to become the chief engineer of a large railroad enterprise in the South. This enterprise having been abandoned by its projectors, he accepted in 1890 the superintendency of the Bertha Zinc Co.'s mines, at Bertha, Va. Here he

introduced the system of mining which has since been used successfully, and which is described in the paper presented by him to the Institute at the Chicago meeting of 1893.* In that year he commenced a general consulting practice, which he carried on, first in Charlotte, N. C., and subsequently in New York city, where in 1876 he founded the firm of Case & Westervelt, mining engineers. He was for many years consulting engineer of the Ducktown copper-mines, in Tennessee. Throughout his career he enjoyed a high reputation for technical skill, integrity and good judgment, and commanded the esteem and affection of those who came into personal relations with him.

John W. Chalfant was born in Allegheny, Pa., December 13, 1827, and died in the same place December 28, 1898. During the seventy-one years of his life he witnessed the wonderful development of the Pittsburgh region, to which, indeed, he was an important contributor. He received his education in the public schools. In 1856 he entered the iron-works of Spang & Co., as a clerk, and, two years later, became a member of the firm, which then took the name of Spang, Chalfant & Co. The numerous positions of trust occupied by him in Pittsburgh and Allegheny attested the esteem in which he was held by his fellow-citizens. He served several times as Presidential Elector, was an officer in many mercantile and charitable institutions; and, in two positions outside of his own firm, namely, as Director of the Pittsburgh Locomotive Works, and as President of the Isabella Furnace Co., he showed his readiness to keep abreast of modern improvements in practice.

In May, 1873, the Institute, numbering 231 members, had been but just fairly launched upon its career, and both the character and the success of its future depended upon the question whether it would be able to command the co-operation of those self-made mining and metallurgical experts and managers who, while they represented the standard of American practice, and knew many things not found in books or taught in schools, were, to some extent, inclined to hold themselves aloof from association with technical graduates and "theorists," from motives, sometimes of morbid modesty, sometimes of conscious superiority in actual experience.

* *Trans.*, xxii., p. 511.

To Mr. Chalfant, who, with other leading ironmasters, following the lead of "Father" David Thomas, came forward at that time, and lent to the Institute hearty and substantial support, it owes a perpetual debt of gratitude.

Thomas S. Disston was born in 1833, and was for many years connected with the famous Keystone Saw, Tool, Steel and File Works of Henry Disston & Sons, Philadelphia. For the last few years of his life he had been active chiefly as a valued adviser to his associates, to whom he had resigned the burdens of management. He was a thorough mechanic; and his inventions and ideas contributed much to the success of the firm of which he was a member.

Mr. Disston became a member of the Institute in 1884; and in connection with the Philadelphia meeting of that year, as well as on subsequent occasions, both at the Disston works at Tacony, near Philadelphia, and on the property of the Disston Land Co., in Florida,* the members of the Institute have been cordially received.

Charles E. Emery, Ph.D., who died June 1, 1898, was born at Aurora, N. Y., in 1838, and received his early training at the Canandaigua Academy, in a railway-shop and draughting-room in a local foundry and machine-shop, and in practical work as a surveyor and civil engineer. At the call of President Lincoln in May, 1861, he volunteered first as a soldier, and afterwards sought service in the navy, in which, after passing the requisite examination he became a third assistant engineer in June, 1861, and served in blockade-duty and in several naval battles throughout the war, during which he was promoted to a higher grade. At the end of the war he was detailed to take part in the steam-expansion experiments of the navy in New York, and remained thus employed until he resigned at the close of 1867, and was appointed consulting engineer in the U. S. Coast Survey and Revenue Service. In this capacity he designed the engines for a score of revenue cutters; the performances of which, together with his experiments on simple and compound engines and the determination of their efficiency, gave him a wide reputation as an investigator and authority in this department. The results of his researches form the basis of much of

* *Trans.*, xiii., p. 299; xxv., p. xxix.

the instruction given in modern treatises on the steam-engine. They won for him many distinctions, among which may be mentioned the honorary degree of Ph.D. from the University of the City of New York, and the Telford Medal from the British Institution of Civil Engineers.

As the engineer and manager from 1881 to 1887 of the New York Steam Company,* "he performed the most remarkable work of his time in the distribution of heat and power from a central steam-plant; and his construction was not only the largest, but almost the only one attempted on a large scale which has proved a successful piece of engineering."†

Dr. Emery was specially eminent as a mechanical engineer; and the record of his multifarious work as a professional writer, consulting engineer, professional expert in the courts, lecturer at Sibley College, Cornell University, etc., must be sought outside of our *Transactions*. But he was an interested and steadfast member of the Institute, which he joined in 1880, and to which he rendered for many years an important continuous service, without thought of recognition or reward. Namely, as a member of the Finance Committee, he examined monthly all the accounts and vouchers of the Secretary's office, and endorsed the drafts upon the Treasurer through which alone the monthly payments could be made. This labor, performed with conscientious thoroughness and with unfailing promptness, constituted a proof of his interest in the Institute, the greatest, perhaps, that a busy man could offer.

James Barnett Goodwillie was born at Cleveland, Ohio, in 1873, entered the Sheffield Scientific School of Yale University in 1891, and graduated with the degree of Ph.B. in 1894, after which he took a post-graduate course in mining and metallurgy at the Massachusetts Institute of Technology. In 1895 he entered the employ of the Johnson Steel Company, at South Lorraine, O., and in 1897 he became connected with the Buckeye Malleable Iron and Coupler Company, Columbus, O. His death from pneumonia, after a brief illness, April 30, 1898,

* See "The Distribution of Steam in Cities," *Trans.*, xii., 632. Also for a reference to one of his important inventions, *Trans.*, x., 364.

† This opinion is quoted from the biographical notice of Dr. Emery published in Circular No. 579, August 20, 1898, of the New York Commandery of the Military Order of the Loyal Legion, and signed by Robert H. Thurston, Theodore Cooper and William H. Wiley. It rests, therefore, on unimpeachable authority.

cut short a career of much promise. As he had become a member of the Institute but a few months before, we have to lament the loss of the service which he might have rendered if longer spared to pursue the work for which he had been so thoroughly prepared, and was, as his instructors and associates declare, so well suited.

Rowland Hazard was born at Newport, R. I., August 16, 1829, and died August 16, 1898, on the sixty-ninth anniversary of his birth. He had been an Associate of the Institute for eleven years, but his appreciation of its work dated from a much earlier period; for it was in connection with the St. Louis meeting, May, 1874, that an excursion was made to the famous old Mine la Motte, and Mr. Hazard—who had just purchased, or decided to purchase, that property—accompanied the party as a guest, and made, en route, quiet observations and discreet inquiries, with the purpose of deciding upon a suitable professional manager. As a result, in large part, of that trip, Mr. W. B. Cogswell was selected to manage Mine La Motte, and its record for succeeding years, surpassing its past history, ratified the choice. Mr. Cogswell was afterwards transferred to Syracuse, where he constructed, and managed for many years, the works of the Solvay Process Co., operating the ammonia process for the manufacture of soda, etc. The remarkable success of this company, of which Mr. Hazard was President, is familiar to all.

Mr. Hazard became an Associate of the Institute in 1887; and both at Mine la Motte and at Syracuse he employed many members of the Institute as metallurgists, chemists or mechanical engineers. The same may be said of the more recent enterprise in which he was engaged, in connection with the introduction into this country of the Semet-Solvay coke-oven. Yet, all the while, his own special knowledge and activity was in a totally different business, namely, the textile mills at Peace Dale, R. I., in the management of which he established his reputation as a successful manufacturer, a just and kindly employer, and a philanthropist both earnest and wise. Into all the enterprises which he controlled he introduced the principle of profit-sharing, besides making provision for the intellectual and social needs of employees. With regard to the undertakings mentioned above as specially appropriate in this place, the most

noteworthy fact is, that Mr. Hazard engaged in them largely on the strength of the knowledge of other men, to whom, after selecting them as competent and trustworthy, he gave his entire confidence. Such an example merits grateful recognition from the Institute.

Thomas Hoatson was born March 13, 1825, in Dumfrieshire, Scotland, and came to America in 1852. In 1853 he began work as miner and tributor at the Bruce copper-mine, Ontario, Canada. In 1865 he became assistant captain of the Quincy mine, Houghton county, Mich.; in 1866 agent of the Ridge mine, Ontonagon county; and in 1871 mining superintendent of the Calumet and Hecla Mining Co., which position he held until his death, December 19, 1897. The general manager of the company briefly sums up his character in the words: "An able man, beloved and respected by all who knew him." Mr. Hoatson became a member of the Institute in 1880, but, like many other experienced and skilful mine-captains, was always too hard-pressed with his daily duties to find time for the unfamiliar work of recording his knowledge for the benefit of others. It is sad to reflect how many valuable facts and suggestions have thus been lost to the profession.

James P. Hosie had been a member of the Institute since 1889. His father, John Hosie, was one of the leading coal-mining engineers of the anthracite region, having opened, together with Mr. Archibald, the mines of the Delaware and Hudson Coal Co., and for some years superintended the operations of the Pennsylvania Coal Co., at Pittston. The son commenced his career as a mining engineer as the assistant of his father, in the sinking of the Kidder slope, now the property of the Lehigh and Wilkes-Barre Coal Co. After that he was assistant superintendent of the Bear Ridge colliery, at Mahanoy City, and at a later period he had charge of the Silver Brook colliery of Hosie & Longstreet. He also opened the Fairlawn colliery, of which he was part-owner. Still later he held an interest in the Edgerton colliery, after disposing of which he was for two years President of the Lytle Coal Co. This terminated his active connection with the coal-business.

Meanwhile, in the earlier part of his career, he had been for some years a civil engineer in the corps of the Lehigh Valley R. R. Co., and was one of the assistant engineers of the Nes-

quehoning tunnel, having charge of the work at the west end. This work was regarded at the time as the most rapid on record in the driving of railway-tunnels.

Morris P. Janney, who died at Pottstown, Pa., November 30, 1898, was born in Philadelphia, February 1, 1850. Upon his graduation in 1869 from the Philadelphia Polytechnic College, he entered the service of the Pottstown Iron Co., where he remained sixteen years, becoming manager of the blast-furnace and mechanical engineer of the rolling-mill. In 1885 he took charge of the Leesport furnace, and in 1886 of the Glendon Iron Co. In 1890 he returned to Pottstown (where he had already a business interest in the firm of Janney & Wickersham, founders and machinists), and soon became again connected with the Pottstown Iron Co. as mechanical engineer. Gradually failing health compelled him to give up active work several years before his death. Mr. Janney became a member of the Institute in 1874, and retained his interest in it to the last.

Edward Cabot Koch was born in New York City, September 3, 1859, and graduated as a mining engineer from the Columbia College School of Mines in 1879. From 1879 to 1889 he was practicing his profession in Colorado, being employed from 1881 to 1888 by the Little Annie Gold Mining Co., at Summitville. From 1889 to 1897 he was with the Elmore Gold Mining Co., at Rocky Bar, Idaho. In the latter year he came to New York, intending to make it his residence, while he attended to interests which he had acquired in Nova Scotia coal-mines. It was at this time, also, that he first became a member of the Institute, which had reason to expect from his comparative leisure much valuable fruit of his previous field-experience. But death had already claimed him. After an illness of several months, and a surgical operation which revealed, but could not remove, the internal malignant tumor which was the hidden cause, he died July 28, 1898.

S. W. McKeown was born April 5, 1842, at North Lima, O., and, like many other young Americans, was obliged to get his education largely at his own expense. In 1859 and 1860 he was a school-teacher, but he left that occupation to return to the studies which it had interrupted. He subsequently established himself in Youngstown, O., as a member of a firm of

druggists and booksellers—a business which permitted him to continue the pursuit of analytical chemistry, which ultimately became his occupation. He was, perhaps, the first analytical chemist who opened a laboratory in the Youngstown iron-region; and his careful and trustworthy work doubtless did much to recommend the aid of chemistry to local furnace-men and founders, and thus to promote the development of a scientific and successful iron industry. Mr. McKeown's examinations of the Mesabi iron range, in 1892, did much to arouse the attention of Cleveland and Pittsburgh capitalists to its great prospective value. In the latter years of his life he gave much of his time to microscopic work, in certain lines of which he was considered an authority. Mr. McKeown joined the Institute in 1883, but never found time to contribute to its *Transactions.* His death by pneumonia, February 12, 1898, in his 57th year, deprived the Institute of a member who might have been expected yet to do much valuable work.

Joseph Curtis Platt, one of the early members, and, in the years 1894 and 1895, a Vice-president of the Institute, was born in 1845 at Fair Haven, Conn., and graduated in 1866 from the Rensselaer Polytechnic Institute, of which he became in 1882, and remained until his death, a Trustee. After his graduation he was employed for three years at the Lackawanna iron-works, Scranton, Pa.; then for a year on the New Haven, Middletown and Willimantic railroad; and, after a few months of renewed service at Scranton, he became, in 1870, engineer of the Boston and Franklinite Co., at Franklin Furnace, N. J., and in 1874 superintendent of its successor, the Franklin Iron Co. In 1875 he took up his residence in Waterford, N. Y., where he died July 7, 1898. He was President of the Mohawk and Hudson Manufacturing Co. and the Eddy Valve Co., and had a large business also as a consulting mechanical and hydraulic engineer. In this capacity he was for some years connected with the department of public works in the City of Brooklyn. As a member of the American Societies of Civil and Mechanical Engineers, he was well known and universally esteemed by those professions.

Mr. Platt joined the Institute in 1873, and was always one of its most enthusiastic and loyal members, testifying his interest by frequent attendance at the meetings, where his genial

presence was expected and enjoyed by hosts of friends, and his words were received with the respect due to his accurate knowledge, large experience and upright character.

Among his contributions to the *Transactions*, the following may be mentioned (to say nothing of occasional, and always interesting remarks in oral discussions, which he did not deem worthy to be written out and published subsequently):

"The Franklinite and Zinc Litigation Concerning the Deposits of Mine Hill, at Franklin Furnace, Sussex County, N. J.," *Trans.*, v., 580 (1877).

"Note on the Defreest Journal-Bearing," *Trans.*, viii., 274 (1879).

Remarks in discussion of various subjects: *Trans.*, xx., 583; xxi., 545; xxiv., 830, 852, 882.

William Starke Rosecrans was born September 6, 1819, at Kingston, O.; graduated at West Point in 1842, and entered the Corps of Engineers of the Army. His career as an officer of that corps, and subsequently as a commander in the Union army during the war, is part of public history, and need not be recounted here. During the interval between 1854, when he resigned from the Engineers, and 1861, when he re-entered the service, he was an architect and civil engineer in Cincinnati; and after his final retirement from the army in 1867 he was Minister to Mexico for a year, after which he took up his residence in California, and busied himself with various enterprises in mining and civil engineering. From 1881 to 1885 he was a member of the House of Representatives from California; and from 1885 to 1893 Register of the United States Treasury. Gen. Rosecrans became a member of the Institute in 1876, and, at the Washington meetings of that year and 1882, cordially co-operated in the entertainment of visiting members. At the Washington meeting of 1890 he was Chairman of the General Committee of Reception, and welcomed the Institute at the opening session in an appreciative address. Though unable to attend later meetings, he retained his membership to the time of his death, which occurred March 11, 1898, after a long illness, at his home near Redondo, Cal.

William Tallman Smith was born in New England in 1834, and began his career in the mercantile business of his brother, at Woonsocket, R. I. In 1861 he took charge of the large

limestone-quarries of the Harris Limerock Co., in the same State, and volunteered in 1862 in a Rhode Island regiment, which served for three months in the defense of Washington. Returning from this brief military episode, he resumed and continued for several years the management of the quarries. He subsequently spent three years in Nevada as Secretary and Treasurer of two Eastern silver-mining companies. In 1870 he was appointed Superintendent of the Mt. Pleasant Coal Co., operating coal-mines at Scranton, Pa. The company went out of business in 1877, and Mr. Smith, securing its coal-lease, managed the property until his death, making it a highly successful enterprise, and winning for himself through his business wisdom and courage the position of an industrial and commercial leader in the Lackawanna region. He was prominent in many prosperous corporations, and not less so in municipal improvements, charities and educational institutions; and the people of Scranton, who esteemed and trusted him, universally mourned his sudden death, the result of heart-disease, which took place in March, 1898, while he was on a journey undertaken for health and recreation. Mr. Smith became a member of the Institute in 1887, and thus lent to it, as so many other leading mine-operators have done, the substantial support and favor without which, no doubt, it would be much harder to secure the active co-operation of technical employees.

Alexander Thielen, of Ruhrort, in Rhenish Prussia, whose death, which occurred in July, 1897, was not reported to the Secretary until after the end of that year, was one of the foremost metallurgical engineers of Germany. The members of the Institute who attended the famous meetings of 1890, when both the Iron and Steel Institute of Great Britain and the *Verein Deutscher Eisenhüttenleute* were its guests, will remember the forceful and agreeable personality of Herr Thielen, and his interesting paper on the Darby Process of Recarburization, and his remarks in discussion of Mr. Gayley's paper on American Blast-furnaces.* The former is a model of complete, compact and candid statement, while the latter exhibit an intelligent recognition of the conditions of the problem presented, coupled with a knowledge of the underlying principles involved in it,

* *Trans.*, xix., 790, 967.

which cannot fail to impress the reader with the thorough mastery of the subject possessed by the author. Mr. Thielen was one of those eminent German engineers and metallurgists who, not content with being the guests of the Institute, have sought to share as members in its work. In 1891 he was elected a member, and continued until death his active support, although unable to take part in the meetings. It is, indeed, upon such evidence of the value of the *Transactions* to remote members, that the expectation of continued prosperity for the Institute mainly rests.

John Gray Torrey was born in 1869, and after graduating from the Stevens Institute, Hoboken, went into business with his father, Herbert G. Torrey, a well-known assayer and metallurgist, who has been for many years in charge of the U. S. Assay Office in New York City. Mr. Torrey joined the Institute in 1890, and became later a life-member. His death, May 27, 1898, not only bereaved his parents, his young wife, and many friends, but cut off the promise of an honorable and useful professional career.

Augustus Stout Van Wickle was born in 1856 at New Brunswick, N. J., and graduated from Brown University, R. I., in 1876, after which he went to Hazleton, Pa., and engaged in the coal-business with his father, at that time President of the Ebervale Coal Co. In 1878 he succeeded to that position, and held it until 1881, when he moved to Cleveland, O., where he was interested in the mining of bituminous coal. In 1888 he returned to Hazleton, where he continued to reside until his death in 1898. He was one of the largest individual anthracite colliery-operators in the region, stood at the head of several manufacturing and mining corporations, etc., and was a public-spirited citizen and a liberal contributor to philanthropic objects. Brown University, Princeton University and Lafayette College were generously remembered in his will. Mr. Van Wickle became a member of the Institute in 1888, upon his return to Hazleton to engage again in the industries and interests of that region, in connection with which he became so prominent.

Thomas J. Waters, who died February 5, 1898, at Coronado Beach, Cal., had been for eight years a well-known mining engineer—the head of the firm of Waters Brothers in Denver, Colo. He was born in Ireland and educated in England and

Germany. After finishing his studies he went to Japan, where he was employed in the construction of important public works, including, as is reported, the design and erection of the Japanese mint. It is said that he had charge subsequently of important constructions in China and New Zealand. After establishing himself in Colorado, he became at one time, with his brother, owner of the well-known Tomboy mine, now belonging to an English company. During the summer of 1897 he was engineer of the Pactolus hydraulic mine at Black Hawk, Colo. Mr. Waters was still in the prime of life when his health failed; and his last journey to Southern California did not avail to save his life. He had been a member of the Institute since 1886.

The Scrutineers reported that the following officers had been elected:

PRESIDENT.

JAMES DOUGLAS, ...	New York City.

VICE-PRESIDENTS.

(To serve two years.)

E. C. POTTER, ...	Chicago, Ill.
GEORGE F. KUNZ, ...	New York City.
W. N. PAGE, ...	Ansted, W. Va.

MANAGERS.

(To serve three years.)

ARTHUR WINSLOW, ...	Kansas City, Mo.
WILLIAM GLENN, ...	Baltimore, Md.
W. J. TAYLOR, ...	Bound Brook, N. J.

TREASURER.

THEODORE D. RAND, ...	Philadelphia, Pa.

SECRETARY.

ROSSITER W. RAYMOND, ...	New York City.

Mr. Douglas, the President elect, was introduced by President Kirchhoff, and, in a few appropriate remarks, accepted his election.

After the passage of a resolution, moved by Mr. John Birkinbine, and instructing the Secretary to acknowledge by suitable official letters the courtesies shown to the Institute by individuals, firms and corporations, not forgetting the efficient and highly successful labors of the Local Committee, the meeting was adjourned.

Papers Presented in Printed Form, and Not Included Above.*

The Rich Patch Iron-Tract, Virginia, by H. M. Chance, Philadelphia, Pa.

The Discovery of New Gold-Districts, by H. M. Chance, Philadelphia, Pa.

Notes on the Operation of a Light Mineral Railroad, by James Douglas, New York City.

The Platinum-Deposits of the Tura River-System, Ural Mountains, Russia, by C. W. Purington, Boston, Mass.

Note on the Disintegration of an Alloy of Nickel and Aluminum, by Erwin S. Sperry, Bridgeport, Conn.

A Prospectors' Density-Rule, by James Holms Pollok, Dublin, Ireland.

The Occurrence, Origin and Chemical Composition of Chromite, with Special Reference to the North Carolina Deposits, by Joseph H. Pratt, Chapel Hill, N. C.

The Abrasive Efficiency of Corundum, by Prof. W. H. Emerson, Atlanta, Ga.

The Gold-Bearing Veins of Bag Bay, near Lake of the Woods, by Peter McKellar, Fort William, Ontario, Canada.

Papers Presented in Manuscript, or Read by Title, for Subsequent Publication and Discussion.

Improvements of the Spring Valley Coal-Mines, Ill., by J. A. Ede, Spring Valley, Ill.

Modern Gold-Mining in the Darien: Notes on the Re-opening of the Espiritu Santo Mine at Cana, by Ernest R. Woakes, Darien Gold Mining Co., Panama, Colombia.

The Patio Process at Guanajuato, by Roberto Fernandez, Guanajuato, Mex.

The Liberty Bell Mine, Telluride, Colo., by Arthur Winslow, Kansas City, Mo.

The Longest Mine-Haulage, by F. Z. Schellenberg, Pittsburgh, Pa.

Correspondence-Schools, by R. P. Rothwell, New York City.

* This list does not include papers of the Buffalo meeting, presented in print at this meeting for the purpose of further discussion.

Iron-Ores of the Potsdam Formation in the Valley of Virginia, by Charles Catlett, Staunton, Va.

The Outfit of Camps and Expeditions, by Chas. H. Snow, University of New York.

Notes on the Geology of Sonora, by E. T. Dumble, Austin, Tex.

Members and Associates Elected.

The following persons were elected members or associates during the sessions of the meeting:

Honorary Members.

Sir W. C. Roberts-Austen,	London, England.
F. Osmond,	Paris, France.

Members.

Walter C. Adams,	Sandon, B. C.
W. T. Adams,	Duluth, Minn.
Rudolph Oswald Ahlers,	Balaghat Mines, Mysore, Southern India
Louis R. Alberger,	New York City.
J. K. Anderson,	Thacker, W. Va.
George Hall Ashley,	Indianapolis, Ind.
Horace H. Atkins, Jr.,	Denver, Colo.
Thomas D. Babbitt,	Boise, Idaho.
Robert W. Barrell,	Deloro, Ontario, Canada.
J. C. Bradley,	Buffalo, N. Y.
Donald Cameron,	Leadville, Colo.
George D. Case,	New York City.
August Christian,	Butte, Mont.
Gordon Clunes,	London, England.
James B. Cooper,	South Lake Linden, Mich.
Francis Harley Davis,	New York City.
Charles Campbell Derby,	New Almaden, Cal.
William Ferdinand Detert,	Jackson, Cal.
James T. Dixon,	Solok, Sumatra, East India.
Andrew Philip Dron,	Big Oak Flat, Cal.
Thomas Russell Drummond,	Bingham Canyon, Utah.
Walter George Files,	Sharon, Pa.
Eliphalet B. Gage,	Prescott, Ariz.
Frank Gilpin,	Colorado Springs, Colo.
George L. Hannahs,	Mercur, Utah.
Frank H. Hartung,	Denver, Colo.
Robert Hobson,	Hamilton, Ontario, Canada.
Harry Holloway,	Marysville, Mont.
John G. Hopper,	Sonora, Cal.
Charles Davis Jameson,	Tientsin, China.
John H. Cordner James,	London, England.

Alexander W. Jolly, . . .	Oorgaum, India.
Ernest W. King, . . .	Gilt Edge, Mont.
Frederick William Linck, . .	Kalgoorlie, Western Australia.
José M. Licona, ...	Chihuahua, Mexico.
John J. Lincoln, . . .	Elkhorn, W. Va.
E. E. Loomis, ...	Elmira, N. Y.
Philip Alexander MacKay, .	Peru, Ill.
Duncan MacLellan, . . .	Valparaiso, Chile.
Charles M. MacNeill, . . .	Colorado Springs, Colo.
George T. McGee, . . .	Kalgoorlie, Western Australia.
Gordon McLean, . . .	Morenci, Ariz.
Hugh Mainwaring Cavenagh-Mainwaring, ...	Southsea, England.
George Mitchell, . . .	Jerome, Ariz.
William G. Nebeker, . . .	Salt Lake City, Utah.
D. W. C. Nelson, . . .	Baker City, Ore.
Michael O'Rourke, . . .	Robinson, Utah.
Frank W. Parmenter, . . .	Mingo Junction, Ohio.
H. H. Patterson, . . .	Toronto, Canada.
J. W. H. Piper, ...	Sydney, New South Wales.
D. G. Putnam, ...	Ashland, Ky.
Carlos Riedt, ...	Mapimi, Mexico.
Thomas M. Righter, . . .	Mount Carmel, Pa.
George W. Riter, . . .	Eureka, Utah.
J. C. Rodriguez, ...	Saltillo, Mexico.
George William Sargent, . .	Reading, Pa.
William Guy Scott, . . .	Soulsbyville, Cal.
Lindsay Scrutton, . . .	London, England.
Vincent F. Shallcross, . .	Kalgoorlie, Western Australia.
H. A. Shipman, ...	Boulder, Colo.
Frank R. Short, ...	Glenbrook, Nevada.
Edwin A. Stevens, . . .	Victor, Colo.
Alfred Walton Stockett, . .	Johannesburg, So. African Rep.
Samuel Storrow, ...	Wapiti, Colo.
Edward Barney Sturgis, . .	Landgraf, W. Va.
Walter G. Swart, . . .	Denver, Colo.
Thomas George Sweet, . .	Broken Hill, New South Wales.
John W. Sylvis, ...	Blue Ridge Springs, Va.
Erik Tamm, ...	Worcester, Mass.
Harold Abbot Titcomb, . .	Los Angeles, Cal.
Charles H. Tompkins, . .	New York City.
William Thompson, . . .	London, England.
George D. B. Turner, . . .	Butte, Mont.
Joseph Burr Tyrrell, . . .	Dawson City, Canada.
Louis R. Wallace, . . .	Morenci, Ariz.
Thomas Leonard Watson, . .	Atlanta, Ga.
F. C. Weber, ...	New York City.
De Bernier Whitaker, . .	Santiago de Cuba, Cuba.
Orvil Robert Whitaker, . .	Arastra, Colo.
Hugh G. C. Whittall, . . .	Constantinople, Turkey.
John R. Williams, . . .	Johannesburg, So. African Rep.

Associates.

James M. Elmer,	Cleveland, O.
Oscar Riker Foster,	Brooklyn, N. Y.
Horatio B. Lewis,	Elk Rapids, Mich.
J. A. Spalding,	Boulder, Colo.
A. G. B. Wilbraham,	Freiberg, Saxony.

Associates Made Members.

Alfred C. Beatty,	New York City.
Rowland F. Hill, Jr.,	New York City.
W. J. Parker, Jr.,	Cleveland, O.
William Allen Smith, Jr.,	Argentine, Kan.
A. F. Williams,	Kimberley, South Africa.

Excursions and Entertainments.

On Tuesday evening, after the opening session, a social reception and supper was given by the Local Committee, with the friendly co-operation of the American Society of Mechanical Engineers, in the house of that society.

On Wednesday, after the morning session, a lunch was provided by the Local Committee, with the friendly co-operation of the authorities of Columbia University.

On Wednesday evening, a brilliant reception and dance, tendered by the Local Committee, and attended by many distinguished invited guests, took place at Sherry's, Fifth Avenue and 44th Street.

On Thursday afternoon excursions were made by different parties as follows:

1. To the New East River Bridge. This bridge, of which L. L. Buck, M. Am. Soc. C. E., is chief engineer, will extend from Norfolk and Delancey Streets, Manhattan, to Broadway and Havemeyer Streets, Brooklyn, a distance of about 7200 feet. It will have a channel-span of 1600 feet and a width of 118 feet, carrying four tracks for trolleys, two tracks for elevated roads, two roadways and two footpaths. The foundations for the steel towers are now practically completed, having been sunk to bed-rock by means of pneumatic caissons, and carried up to their final height, 23 feet above high water.

The work now in progress is the construction of the anchorages. The Manhattan and Brooklyn anchorages are in general similar, though modified in detail, to suit local conditions; but

the methods used by the contractors in handling the work vary materially.

The anchorage on the Manhattan side is nearly 152 feet long and about 178 feet wide at the back. The foundation piles were cut off 17 feet below high water, and a concrete base, resting on a timber grillage, is carried up to 2 feet above high water. From this point the masonry is to be carried up about 103 feet. About 14,000 cubic yards of concrete, 1241 feet B. M. of timber, 43,300 cubic yards of masonry and 1600 tons of steel are included in the contract now being executed on the Manhattan side, where the work on the steel anchorage-platform and on the masonry was under way at the time of the excursion, while in Brooklyn the laying of masonry and placing of the anchor-chains was in progress.

In connection with this excursion, those who desired to do so were enabled to visit the Brooklyn Navy Yard, and also the following works:

The Hecla Iron Works, corner Worth and Berry Streets, Brooklyn, manufacturers of architectural and ornamental work in iron, sheet brass, bronze, copper, aluminum and spelter. Among other departments of interest are those devoted to molding, metal foundries, ornamental blacksmithing, galvano-bronze deposition, and Bower-Barffing. These works were referred to in the discussion on the Kytchtym Medal, at one of the sessions of the meeting, as the pioneers of fine cast-iron work in the United States.

The Worthington Pumping Engine Co., Van Brunt Street, Brooklyn.

2. To the Nichols Chemical Works, Laurel Hill, L. I. A numerous party visited these works, where the departments of special interest were the Manhes Bessemer plant, for bessemerizing copper matte, and the cupola and calcining furnaces.

The company was hospitably received and generously entertained at luncheon by the Nichols Chemical Co.

On Thursday afternoon the visiting members and guests of the Institute were invited to a reception given by Mr. and Mrs. Abram S. Hewitt, at their residence, 9 Lexington Avenue, and attended by a great multitude of local and foreign celebrities, and representatives of New York society.

On Friday, February 24th, an excursion, in which about 200 members and guests participated, was made to the mines and concentration-plant of the New Jersey Zinc Co., at Franklin Furnace, N. J. Luncheon was provided for the party by the company, and the interesting mines and works were hospitably thrown open to inspection.

These mines, located in Sussex county, N. J., have no parallel in other parts of the world. The ore-deposits consist of folded beds in crystalline white limestone. The ore is an intimate mixture of franklinite and willemite, with small amounts of zincite, garnet, fowlerite, tephroite, etc. The deposit has long been renowned as a field for the mineral-collector, a large variety of minerals being found here, some of them unique. There are two deposits about 2 miles apart, one located at Franklin Furnace and the other at Ogdensburg, N. J. At present, work is being carried on only at Franklin Furnace. The southern end of this deposit is being mined by stripping and open-cut work. The limestone, which practically forms the hanging-wall of the deposit and lies in the saddle formed by the ore-bed, is being removed to a depth of a hundred feet. An exceptional opportunity is given here to view the nature and extent of the ore-body.

In all, the deposit has been explored for a length of about 3500 feet, the ore-body varying in thickness from 25 to 200 feet. The so-called front vein of the deposit (the eastern end of the ore-bed cropping to the surface) has been mined in places to a depth of some 600 feet on the incline, but work is not being carried on here at present. The northern end is developed by a vertical three-compartment shaft, sunk to a depth of 1000 feet. The mine is drained by two duplex triple-expansion Worthington pumps, one located at the 600- and one at the 1000-foot level, each having a capacity of 1000 gallons per minute.

The concentration-plant, which is located at this shaft, presents many features of interest. The ore is raised from the mine and passed over a Robins belt-conveyer, which serves as a sorting-table. It is then crushed to ½ inch diameter and dried by means of an Edison tower-dryer, after which it is reduced to 10-mesh and separated into five sizes by means of Edison tower-screens, being carried from one process to the next by

belt-conveyers. Each size is run separately over a magnetic concentrator of the Wetherill type. These machines utilize the Wetherill process of separating ores of very slight magnetic attractability; in fact, such ores, previous to the invention of this process, were considered incapable of magnetic concentration. Over each feed-belt on these machines there are six magnets which divide the product into different classes, depending on the magnetic attractability of the material removed. Three products are obtained: 1. franklinite, from which oxide of zinc and spiegel-eisen are produced; 2. middlings, which consist of a mixture of manganese and iron silicates, as well as some proportion of the willemite which has particles of the franklinite or other magnetic material attached to it (this material is used for production of oxide of zinc only); 3. a mixture of willemite, red oxide of zinc and calcite, practically free from iron and manganese. This product, constituting the tails from the magnetic separator, is passed over jigs which remove the calcite, leaving practically clean willemite and red oxide of zinc, to be used in the spelter-furnace. Almost chemically pure metal is obtained from this material, as it contains no lead, cadmium or other ingredients, such as commonly contaminate spelter.

The concentrating-plant has a capacity of about 350 to 400 tons per day of twenty-four hours. A new concentrating-plant is now in process of erection, which will handle 1000 tons of ore in ten hours. The foundations for this building have been completed, and some of the crushing-machinery, which will be on the Edison principle, is in course of erection. The Edison scheme of crushing does away entirely with the jaw-breaker, handling the material from the beginning with rolls.

An excellent description and complete bibliography of the deposit can be found in *The Ore-Deposits of the United States*, by James F. Kemp, A.B., E.M. Prof. Kemp gave a short talk on the geological and mineralogical features of these deposits on Wednesday, at Columbia University, illustrated with stereopticon pictures, and an exhibition of mineral specimens. A full description of the concentrating-plant, written by J. P. Wetherill, was published in *The E. and M. Journal*, July 17, 1897, page 65.

On Saturday, February 25th, excursions were made to the works of the New Jersey Zinc Co., Newark, N. J., and the Guggenheim Smelting Co., Perth Amboy, N. J.; lunch being provided *en route* by the Local Committee. The works of the New Jersey Zinc Co. exhibited the further metallurgical treatment of the products of the concentration-plant at Franklin Furnace in the manufacture of spelter, zinc oxide and spiegeleisen; and the works of the Wetherill Concentrating Co., also in Newark, and likewise cordially opened to inspection, gave opportunity to those who had not visited Franklin Furnace to see the operation of the Wetherill magnetic concentrators upon so-called "non-magnetic" material.*

The Guggenheim Smelting Co. has an electrolytic copper-refining plant, copper reverberatory-furnaces, and a plant for refining argentiferous base bullion.

The following establishments were also thrown open to the inspection of members and guests at any time düring the meeting, the badge provided by the Local Committee (a very handsome pin, carrying the crossed-hammers of the Institute seal upon a circular shield of blue enamel) being everywhere recognized as entitling the wearer to hospitality:

The Brooklyn Bridge.

The J. L. Mott Iron Works, 2413 Third Avenue. The brass foundry and enameling departments were of special interest.

Power-House of the Third Avenue Railroad Co., 65th Street and Third Avenue.

Tiffany & Co., 15th Street and Union Square. Fine exhibits of rich jewels, silver, bronze and fine porcelains.

Tiffany Glass Co., 333 Fourth Avenue. Manufacture and exhibit of Favrile, Stained and Mosaic glass.

Power-Houses of the Metropolitan Street R. R. Co.: the Broadway cable-plants, at Broadway and Houston Street, and at Sixth Avenue and 50th Street; the Lexington Avenue cable-plant, at 25th street, near Lexington Avenue. In this station is also located about 5000 horse-power of electrical machinery. The balance of the electrical power is generated at the station at Lenox Avenue and 146th Street.

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* See the paper of Messrs. Wilkens and Nitze on "The Magnetic Separation of Non-Magnetic Material," *Trans.*, xxvi., 351.

Edison Electric Illuminating Co.'s power-house, at 53 Duane Street.

The Ball & Wood Co.'s Works, Elizabethport, N. J., building automatic cut-off, high- and medium-pressure engines, from 50 to 1000 horse-power.

The Atha and Illingworth Co., Harrison, N. J., at present employed in melting crucible-steel and making rolled and hammered merchant-bars from ¼ inch to 5 inches, round or square.

The Crocker Wheeler Electric Co., Ampere, N. J. These works are operated entirely by electricity, and contain many new features, such as the direct electric driving of all the large tools by motors built into them.

The Joseph Dixon Crucible Co., Jersey City, N. J. The oldest and largest house in the world in the manufacture of graphite-products.

Courtesies were also extended to visiting members and guests by numerous clubs and associations of the city, among which may be specially mentioned the Press, Lotos, Reform, Hardware and Engineers' Clubs, the New York Academy of Sciences, and the Uptown Association; but, in fact, it may be truly said that there is no social, professional or scientific club or institution in New York into which, either through the official invitation of its managers, or through the personal introduction of a local member, a visiting member of the Institute would not have been assured of a cordial welcome. Hospitalities of this kind were indeed offered far in excess of the ability of members to make use of them.

Members, Associates and Guests Registered.

The following persons were registered at headquarters:

Randolph Adams.
R. Wilson Anderson.
William Atkins.
Louis W. Atkinson.
J. B. Austin.
W. S. Ayres.
F. E. Bachman.
Charles Bailey.
Henry A. Bang.
George Barker.
J. H. Bartlett.
O. C. Beck.
A. C. Bedford.
G. H. Billings.
John Birkinbine.
William Clinton Brown.
T. F. Budlong.
John Allen Capp.
A. Cass Canfield.
Charles Catlett.
W. B. Cogswell.
Robert A. Cook.

Robert L. Cox.
William M. Coyle.
C. F. Chandler.
J. Parke Channing.
Frank D. Chase.
Robert H. Chapman.
J. Russell Clarke.
F. L. Clerc.
G. A. Crocker.
Ellsworth Daggett.
G. V. Davies.
Arthur V. Davis.
W. S. DeCamp.
Axel Dellwik.
C. D. Demond.
W. B. Devereux.
James Douglas.
W. F. Downs.
Benj. I. Drake.
P. H. Dudley.
Theo. Dwight.
A. Eilers.
S. A. Espey.
A. Faber du Faur.
B. F. Fackenthal, Jr.
Michael Fackenthal.
A. S. Farmer.
Edward McC. Fisher.
G. P. L. Fisher.
H. Fisher.
Stanley G. Flagg, Jr.
L. W. Francis.
James W. Fuller, Jr.
Howard Van F. Furman.
Oliver S. Garretson.
Frank Lynwood Garrison.
L. W. Getchell.
William Glenn.
Ely Stanford Godfrey.
Dunbar F. Haasis.
F. H. Harrington.
George W. Harris.
W. J. Harris.
A. Heckscher.
Herman Hegeler.
Julius W. Hegeler.
G. C. Hewett.
George H. Hewitt.
Henry D. Hibbard.
F. N. Hoffstot.
Dr. H. O. Hofman.
Charles T. Holbrook.
Levi Holbrook.
Henry M. Howe.
Geo. S. Humphrey.
W. S. Hungerford.
Alfred E. Hunt.
C. W. Hunt.
Fred. F. Hunt.
Fred. W. Huntington.
Axel O. Ihlseng.
David S. Jacobus.
Clemens C. Jones.
Fred. D. Jones.
John N. Judson.
Howard Allan Keeler.
Edward Keller.
Arthur H. Keller.
J. F. Kemp.
William Kent.
William St. G. Kent.
F. Kimball.
Paul S. King.
Charles Kirchhoff.
George F. Knapp.
F. H. Knight.
S. R. Krom.
George F. Kunz.
J. Langeloth.
L. G. Laureau.
Albert R. Ledoux.
J. Henry Lee.
Stephen S. Lee.
E. A. Lewald.
James F. Lewis.
C. Lihme.
N. Lilienberg.
Stuart Lindsley.
P. S. Linhard.
Orleans Longacre.
Burdett Loomis.
R. F. Lord.
Hjalmar Lundbohm.
Richard S. McCaffery.
W. C. McFarland.
James MacNaughton.
Harris K. Masters.
E. P. Mathewson.
Tamé Matsmoto.
Charles C. Mattes.
Charles O. Mattes.
William F. Mattes.
George W. Maynard.
Gurdon M. Maynard.
D. Ernest Melliss.
F. J. H. Merrill.
W. B. Middleton.
Spencer Miller.
John D. Moore.
Otto A. Moses.

Edgar C. Moxham.
Henry S. Munroe.
Frank Nicholson.
H. B. C. Nitze.
E. E. Olcott.
George D. Ormrod.
I. P. Pardee.
Edward W. Parker.
C. Q. Payne.
Matthew Penhale.
Frederic Emery Pierce.
William H. Pierce.
Prof. S. M. Pitman.
John B. Porter.
Chester W. Purington.
Frank H. Purington.
A. Raht.
Addison C. Rand.
Charles F. Rand.
Theo. D. Rand.
James B. Randol.
John C. F. Randolph.
R. W. Raymond.
Jesse W. Reno.
Jacob M. Rich.
Prof. Robert H. Richards.
Geo. B. Richardson.
Dr. P. De P. Ricketts.
John J. Ridgway.
A. M. Robeson.
Thomas Robins, Jr.
F. Roeser.
Auguste J. Rossi.
R. P. Rothwell.
Louis Ruhl.
S. Sanford.
E. J. Schmitz.
Chas. C. Schnatterbeck.
Albert F. Schneider.
H. J. Seaman.
A. W. Sheafer.
John M. Sherrerd.
Francis M. Simonds.
A. P. Smith.
J. Bennett Smith.
Oberlin Smith.
John C Smock.
Charles H. Snow.
Edwin A. Sperry.
Albert Spies.
E. G. Spilsbury.
Harry H. Stock.
George C Stone.
L. Strauss.
Joseph Struthers.
Knox Taylor.
L. H. Taylor, Jr.
W. J. Taylor.
A. Thies.
John M. Thomas.
Charles H. Tompkins.
James B. Tonking.
William H. Tonking.
Herbert G. Torrey.
Charles C. Upham.
Dudley Van Ingen.
Joseph A. Van Mater.
William Van Slooten.
Leonard Waldo.
Arthur L. Walker.
John A. Walker.
William d'H. Washington.
Walter L. Watson.
F. C. Weber.
William R. Webster.
Charles G. Weir.
Moritz Weiss.
H. L. Wheelock.
Jerome Wheelock.
S. Whinery.
William H. Wiley.
Henry A. J. Wilkens.
David Williams.
Joseph L. Wills.
Arthur Winslow.

To this total of 211 should be added the number of ladies accompanying members, which will increase the number to 261. But on this occasion, no doubt, as at previous meetings, many members and guests, not staying at the Murray Hill Hotel, failed to register their names.

Proceedings of the Seventy-Seventh Meeting, San Francisco, California, September, 1899.

COMMITTEES.

General Executive and Excursion Committee.—W. C. Ralston, *Chairman;* Hon. J. H. Neff, Charles G. Yale, J. F. Halloran, Judge E. A. Belcher, Harold T. Power, A. D. Foote, B. S. Rector, W. F. Detert, E. C. Voorhies, J. F. Parks, Thomas Hender, W. H. McClintock, P. A. Buell, Charles C. Derby, H. E. Picket, Fred. W. Bradley, Curtis H. Lindley, S. B. Christy, W. S. Keyes, Capt. Thomas Mein, A. A. Watkins, W. B. Bourne, Fred. Zeitler, W. P. Hammon, F. F. Thomas, John Ross, Jr., D. R. Oliver, Fred. Wilmans, Mark B. Kerr, Frank A. Leach, J. J. Crawford, M. E. Dittmar, Lew E. Aubury.

Reception Committee.—Hon. James D. Phelan, Hon. Tirey L. Ford, Daniel M. Burns, R. S. Moore, S. J. Hendy, Tyler Henshaw, S. Mooney, Andrew Carrigan, Joseph Sloss, Edward Coleman, James S. Brownell, John Bermingham, P. George Gow, A. J. Ralston, Hon. Henry T. Gage, Irving M. Scott, W. W. Montague, James Spiers, Jr., B. T. Lacy, H. T. Lally, Col. George H. Wallis, John M. Wright, John F. Davis, W. A. Doble, George Johnson, Julian Sonntag, P. N. Lilienthal, Louis Glass.

General Secretary of Local Committees.—Edward H. Benjamin.

Hotel Headquarters.—The Palace Hotel.

The first session was held at the Palace Hotel, on Monday, September 25, 1899, at 1.30 P.M.

Mr. William C. Ralston, Chairman of the General Committee, called the meeting to order, and spoke as follows:

Mr. President, and Members and Guests of the Institute: Hon. J. H. Neff, the President of the California Miners' Association, being obliged to leave us this morning and return to Colfax upon important business, has requested me, as Vice-President of the Association, to extend to you to-day, in its name, the hand of welcome.

It is hoped that we shall be able, during the time you spend with us, to show you how welcome you are, without having very often to tell you so. And it goes without saying that the ladies who accompany you are doubly welcome. I am sure they have already observed that fact.

The Association of which I have the honor to be an officer does not pretend to represent the State of California. Its members represent the mining industry of the State, which is what

particularly interests you. But, at the same time, all our citizens join hands in cordial hospitality when a distinguished body like the Institute visits California; and you may rest assured of receiving attention from all, whether they be miners or not.

It is scarcely necessary for me, at this time, to tell you much about our mining industry. It is our intention to show you several of the representative mines and mining districts before you return to your homes.

Some of you have already seen at Keswick, *en route* to this meeting, the beginning of a copper industry, which, while it cannot yet challenge comparison with the full growth of this branch of mining and metallurgy in Montana and Arizona, is indicative of what may be achieved in that direction by the adequate investment of capital in the copper-deposits of our State.

That the gold-mining of California is now at maturity, you will shortly see for yourselves. For more than fifty years we have been taking gold from our gravels and our quartz-veins; and the supply still holds out. We are now giving to the channels of trade and finance sixteen or seventeen millions of dollars in gold every year, and this production shows at present, from year to year, a slow but steady increase. This, I may add, is being done upon a very small investment of capital, as compared with the outlay required in other States for like results. We have always lacked capital for our gold-mines, and have had to get on as best we could without it. We are so far from the great money-centers as to be practically out of the line of such investments. For this reason, you must not expect to see, in your visit to our mining regions, such magnificent plants as are to be found in Montana and Colorado. Those which you will see have been largely paid for by the product of the mines themselves, and have grown as the development of the mines have both demanded and warranted increased facilities.

It is hoped that some useful lessons may be learned from an inspection of the conditions as they exist, and of the results that have been accomplished under the pressure of necessity. We ourselves have learned many such lessons, and have taught them to others. As the pioneers in gold-mining of all this western country, we have originated many mechanical devices

and methods, which have been improved, both here and elsewhere, by the combined agencies of science and practice.

For nearly fifty years, California led all the States and Territories of the Union in annual gold-product, and was, during some of those years, in the happy position of ability to do heroic work in supporting the financial standing of the nation at the time of its greatest need. Our aggregate yield of gold has been nearly double that of any other State or Territory. While our surface-placers are practically exhausted, there remain untouched hundreds of miles of buried river-channels, filled with auriferous gravel, and thousands of undeveloped quartz-veins. We hope to secure your influence in assisting us to open many of these sources of wealth.

We feel sure that your inspection of California will convince you that our mining industry is not in a state of decadence; that, as a mining State, California is not "played out." We are now producing from our mineral resources more than $27,000,000 a year; and this product has been steadily increasing for the past six years. Our petroleum and asphalt industries, like our copper-industry, are but just beginning to receive recognition and development; and many other minerals are mined in our State, as you will find upon examination of the souvenir volume which will be presented to you for more leisurely consideration, and to which I will refer you for details necessarily omitted from these brief remarks.

Concerning this volume,* I beg to say that it has been prepared, as a labor of love, by experts in the respective branches upon which they have written. What the labor of compiling and editing it has been, our worthy Secretary, Mr. Benjamin,

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* SECRETARY'S NOTE.—"*California Mines and Minerals.* Published by the California Miners' Association, under the direction of Edward H. Benjamin, Secretary, for the California Meeting of the American Institute of Mining Engineers. San Francisco, 1899."

This volume, an octavo of 450 pages, profusely illustrated and handsomely printed and bound, was presented to every member of the Institute attending the California meeting; and, with a liberality unprecedented in similar cases, copies were furnished to the Secretary of the Institute for distribution to all members throughout the world. Notwithstanding the lavish hospitality in other respects poured upon its guests by the California Miners' Association, in connection with this meeting, it may be said without hesitation that the preparation and presentation of this splendid account of the present mining and metallurgical industries of California was the most appropriate and the most memorable of all the attentions which the combined generosity and ingenuity of our hosts devised. R. W. R.

best knows. We, like you, have to depend much on our Secretary, and are fortunate in having the right man in the right place.

Please do not consider yourselves at any time as under obligations to us as your hosts. Indeed, the obligation is all the other way. We feel deeply indebted to you for coming so far to make us a friendly call. To use an old expression, "If you dont't see what you want, ask for it!" We will try to get it for you, if it is to be had. Everything is at your disposal, so far as we can make it so. The expression in our new national hymn about "a hot time" is but a phrase of hospitality. You have already had a sample of it, both figuratively and literally, at Keswick.* There is more of the same sort of greeting (perhaps, also, of weather!) awaiting you in the foothills and mountains where our miners live;—and we will let them do the rest of the talking!

President James Douglas responded as follows:

I regret that we cannot return thanks to Mr. Neff personally for the splendid welcome we have received; but we are fortunate in his substitute. If there is a name in California, Mr. Ralston, which every one who knows the annals of the State links with its early history and its marvelous progress, it is your name. Your father stood for all that was most progressive and most noble among the Argonauts of California. I am sure it is with intense pleasure that the members of the Institute here present greet their fellow-member, his son.

You have spoken of the mechanical appliances in aid of mining and metallurgy which have had their origin in California. I think California set the example of automaticity in metallurgy. There is no more perfect instance of automaticity than a fully-equipped gold stamp-mill; and I cannot help thinking that it was the example of the gold stamp-mill that, more or less, influenced our manufacturers of iron and steel and other metals to introduce the same principle into their works, until to-day, machinery, rather than manual labor, effects, from first to last, all our great metallurgical operations.

* SECRETARY'S NOTE.—The temperature at Keswick, during the visit of the Institute party, was 108° F. in the shade. R. W. R.

This leads me to the subject which I have chosen for my official address to the Institute.

[Dr. Douglas proceeded to deliver the Presidential Address, which will be found on p. 648.

The following paper was read and discussed:

The Origin of the Yosemite Valley, and the Eroding Effect of Glaciers, by Prof. W. P. Blake, Tucson, Arizona.

The second session was held at the Palace Hotel, September 26th, at 9.30 A.M., when the following paper was read:

The Electromotive Force of Metals in Cyanide Solutions, by Prof. S. B. Christy, University of California, Berkeley, Cal.*

The Secretary announced invitations from the Mechanics' Institute to attend its annual exhibition (at which the prize plans for the future buildings of the University of California were on exhibition), and cordial invitations from various clubs, societies and firms, in San Francisco; and called attention to the souvenir volume, "California Mines and Minerals," a copy of which awaited the receipt of each member present.

The third session was held at the Palace Hotel, September 27th, at 9.30 A.M.

The following papers were read and discussed:

The Natural Coke of the Santa Clara Coal-Field, Sonora, Mexico, by E. T. Dumble, Houston, Texas.

The Geology of Arizona, by Prof. Theodore B. Comstock, Los Angeles, Cal.

Tangential Water-Wheels, by W. A. Doble, San Francisco, Cal.

Reminiscences of the Early Anthracite-Iron Industry, by Samuel Thomas, Catasauqua, Pa.

The Secretary announced that, by order of the Council, he was instructed to express, in separate letters to the individuals, committees, friends and corporations concerned, the thanks of the Institute for the overwhelming courtesy and hospitality shown to its visiting members and guests.

* This elaborate and important paper, the manuscript of which was received too late for publication in the present volume, will be issued hereafter.

After sundry notices relative to excursions and entertainments, the meeting was adjourned.

Papers Presented in Print, Not Included Above.

At the sessions of this meeting, the following papers were presented in print, and opportunity was given for their discussion:

Note on Plate-Amalgamation, by Allan J. Clark, Lead, South Dakota.

The Mines and Mill of the Atacama Mineral Company, Ltd., Taltal, Chile, by Sydney H. Loram, Essex, England.

Investigation of Magnetic Iron-Ores from Eastern Ontario, by Frederick J. Pope, New York City.

The Relative Desulphurizing Effect of Lime and Magnesia in the Iron Blast-Furnace, by O. R. Foster, Brooklyn, N. Y.

The Peculiar Ore-Deposit of the East Murchison United Gold Mine, Western Australia, by D. P. Mitchell, Palo Alto, Cal.

The Occurrence of Tin-Ore at Sain Alto, Zacatecas, with Reference to Similar Deposits in San Luis Potosi and Durango, Mexico, by Edward Halse, Colombia, S. A.

The Copper-Deposits of Vancouver Island, by William M. Brewer, Victoria, B. C., Canada.

Rock-Salt in Louisiana, by A. F. Lucas, Lafayette, La.

The Lee Long-Wall Mining Machine, by H. Foster Bain, Des Moines, Iowa.

American Transcontinental Lines, by James Douglas, New York City.

Physical Tests of Some Pacific Coast Timbers, by Frank Soulé, Berkeley, Cal.

Notes on the Life of Steel Wire Cables, by Frank Soulé, Berkeley, Cal.

Papers Read by Title, for Subsequent Publication and Discussion.

The Effect of Heat-Treatment upon the Physical Properties and the Micro-Structure of Medium-Carbon Steel, by Robert G. Morse, Jamaica Plain, Mass.

The Temperature at which Certain Ferrous and Calcic Sili-

cates are Formed in Fusion, and the Effect upon these Temperatures of the Presence of Certain Metallic Oxides, by H. O. Hofman, Boston, Mass.

Nickel-Steel, a Synopsis of Experiment and Opinion, by David H. Browne, Cleveland, Ohio.

The Bryan Mill as a Crusher and Amalgamator Compared with the Stamp-Battery, by E. A. H. Tays, Sinaloa, Mexico.

The Manganese-Deposits of Bahia, Brazil, by J. C. Branner, Stanford University, Cal.

Cyaniding in New Zealand, by James Park, Thames, Auckland, New Zealand.

The La Grange Dam, California, by E. H. Barton, Robinsons, Cal.

Stoping with Machine-Drills, by Bert. Thane, Chief Mine, Sumdum, Alaska.

Deep Mining at the Utica Mine, by J. H. Collier, Tesla, Cal.

Continued Discussion of Mr. Scott's Paper (*Trans.*, xxviii., 679) on Mine-Surveying Instruments, containing an important contribution (amounting to a separate paper) from H. D. Hoskold, Inspector-General of Mines of the Argentine Republic.

Members and Associates Elected.

The following persons were elected members or associates:*

Members.

Leigh Allan,	Tacoma, Wash.
Carl E. Ambrosius,	Guanacevi, Durango, Mexico.
Julius Ambrosius,	Guanacevi, Durango, Mexico.
Eugene Antz,	Cuprum, Idaho.
John W. Archibald,	Coolgardie, West Australia.
Stephen Badlam,	Duquesne, Pa.
Owen S. Batchelor,	Victoria, British Columbia, Canada.
John Wainwright Bell,	Yreka, Cal.
Edward H. Benjamin,	San Francisco, Cal.
N. S. Berray,	Pearce, Ariz.
J. Walter Best,	Denver, Colo.

* This list includes only those candidates whose names were sent to members by mail in Circulars Nos. 3 and 4, June 12 and August 10, 1899. A large number of proposals received after the latter date, and during the period of the meeting and excursions, could not be properly considered by the Council under the circumstances, and were therefore held for subsequent action and election by postal ballot. But all persons duly proposed for membership were invited to take part, as guests of the Institute, in the sessions and excursions of the meeting.

R. M. Bibb, ...	Roanoke, Va.
William H. Boorne, . .	London, England.
W. E. Booth, . . .	Hamby Station, Ky.
Hermann A. Brassert, . .	Braddock, Pa.
S. E. Bretherton, . . .	Silver City, New Mexico.
Robert B. Brinsmade, . .	Butte, Mont.
Frederick E. Budd, . .	Sparrow's Point, Md.
Charles W. Burrows, . .	Dapto, New South Wales.
R. H. Burrows, . . .	Cripple Creek, Colo.
Andrew Burt, . . .	Tientsin, North China.
B. F. Bush, ...	Roslyn, Wash.
John Cabot, Jr., . . .	New York City.
F. J. Campbell, . . .	Denver, Colo.
Norman Carmichael, . .	Nelson, B. C., Canada.
Arthur Chippendale, . .	Sultepec, Mexico.
George M. Clark, . . .	Placerville, Cal.
Lindesay C. Clark, . .	Mt. Lyell, Tasmania.
V. V. Clark, ...	Bland, New Mexico.
James I. Cowan, . . .	Saratoga, Wyoming.
Jennings S. Cox, Jr., . .	New York City.
Robert E. Cranston, . .	Folsom, Cal.
David T. Croxton, . .	Canal Dover, Ohio.
Eckley S. Cunningham, .	Carbonado, Mont.
Francis J. Dennis, . .	Menzies, Western Australia.
Herman Dickman, . .	Johannesburg, South African Republic.
Arthur Dieseldorff, . .	Freiburg in Baden, Germany.
Lewis A. Dunham, . .	El Paso, Texas.
J. H. Emerson, . . .	Victor, Colo.
Frank Escher, . . .	El Paso, Texas.
David Thomas Evans, . .	Powellton, Fayette Co., W. Va.
Achille Falco, . . .	Prescott, Ariz.
W. F. Ferrier, . . .	Rossland, B. C., Canada.
Charles W. Fielding, . .	London, England.
H. P. Fogh, ...	Roslyn, Wash.
Perfecto Gomez, . . .	Zacualpan, Mexico.
Gillmore Goodland, . .	London, England.
Charles J. Gould, . . .	Cornwall, England.
P. George Gow, . . .	San Francisco, Cal.
Ernest Graham, . . .	Charters Towers, N. Queensland, Australia.
R. J. Grant, ...	Victor, Colo.
Fred. T. Greene, . . .	Butte, Mont.
Frank N. Guild, . . .	Tucson, Ariz.
Charles A. Hamilton, . .	San Francisco, Cal.
Henry L. Hancock, . .	Moonta Mines, So. Australia.
A. C. Hardison, . . .	San Domingo Mines, Carabaya, Peru.
William Hawdon, . . .	Middlesboro-on-Tees, England.
F. R. Hazard, . . .	Syracuse, N. Y.
Herman Hegeler, . . .	La Salle, Ill.
Ernest A. Hersam, . .	Berkeley, Cal.
Robert J. Hilton, . . .	Salt Lake City, Utah.
Frank A. Holdsworth, . .	Maratoto, New Zealand.
Edward Hopkins, . . .	Lexington, N. C.

Albert W. Hudson, . .	Captains Flat, New South Wales.
A. K. Johnston, . . .	Staten Island, N. Y.
John T. Keegan, . . .	Magee, Boise Co., Idaho.
Cornelius H. Keller, . .	Aguas Calientes, Mexico.
Charles R. Keyes, . . .	Des Moines, Iowa.
Clarence King, . . .	New York City.
Norman M. Kirkcaldy, . .	Dunedin, New Zealand.
Peter Kirkegaard, . .	Deloro, Ontario, Canada.
Charles Kleinschmidt, . .	Guanacevi, Durango, Mexico.
Henry Marquette Lane, .	Scranton, Pa.
Schuyler Lawrence, . .	Barranca de Cobre, Chihuahua, Mexico.
C. B. Lihme, . . .	Peru, Ill.
John A. M. Lindsay, . .	Broken Hill, New South Wales.
James B. Little, . . .	Johannesburg, South African Republic.
William H. McCord, . .	Amador City, Cal.
William A. Macleod, . .	Rat Portage, Ontario, Canada.
Parrington M. McCree, . .	Bingham Cañon, Utah.
Simon S. Martin, . . .	Sparrow's Point, Md.
Paul Mellors, . . .	London, England.
Joseph Miller, . . .	Day Dawn, Murchison, Western Australia.
C. E. Mitchener, . . .	New Philadelphia, Ohio.
Hamilton L. Moulder, . .	Minas Prietas, Torres, Mexico.
Charles H. Munro, . .	Dutch Flat, Cal.
John E. Norman, . . .	Denver, Colo.
Henry Noyes, . . .	Melbourne, Australia.
William Oswald, . . .	Coblenz, Germany.
J. M. Parfet, ...	Cripple Creek, Colo.
Richard Frank Pearce, . .	Butte, Mont.
Frederick John Pope, . .	New York City.
Aloÿs Preisser, . . .	Hillsboro, Sierra Co., New Mexico.
Benjamin G. Randall, . .	Campo Seco, Cal.
H. MacKenzie Ridge, . .	Broken Hill, New South Wales.
Louis Rosenfeld, . . .	San Francisco, Cal.
E. L. Shaffer, . . .	Victor, Colo.
Angus Snedaker, . . .	Denver, Colo.
Frederick T. Snyder, . .	Kingston, Canada.
Julian Sonntag, . . .	San Francisco, Cal.
Thomas W. Stiles, . . .	New York City.
Franklin T. Sutherland, .	Placer, Ore.
John A. Taylor, . . .	San Fernando, Durango, Mexico.
T. L. Thomas, . . .	New York City.
William S. Thyng, . .	Roselle, N. J.
Frank W. Traphagen, . .	Bozeman, Mont.
Stephen W. Vale, . . .	Adelong, New South Wales.
Edward C. Voorhies, . .	Sutter Creek, Cal.
Otto Wagner, . . .	New York City.
Henry B. Warren, . . .	Vancouver, B. C., Canada.
G. W. Wepfer, . . .	Johannesburg, South African Republic.
Archer E. Wheeler, . .	Great Falls, Mont.
Frederick de L. Williams, .	London, England.
Todd C. Woodworth, . .	Plymouth, Cal.

Associates.

Walter J. Bartnett,	San Francisco, Cal.
Horatio S. Bonestell,	San Mateo, Cal.
Francis E. Corbett,	Butte, Mont.
Louis Davidson,	Newcastle-on-Tyne, England.
Walter E. Downs,	Sutter Creek, Cal.
Thomas W Griggs,	Davenport, Iowa.
John Robert Healy,	Boston, Mass.
Thomas J. Hurley,	New York City.
Hugh F. Kendall,	Cambridge, Mass.
Carl E. Knecht,	Los Angeles, Cal.
Harry H. Lee,	Denver, Colo.
George B. Leighton,	St. Louis, Mo.
Clancey M. Lewis,	Canton, China.
Robert G. Morse,	Joliet, Ill.
William H. Porter,	New York City.
John R. Powell,	Denver, Colo.
James F. Sanborn,	Cambridge, Mass.
John R. Stanton,	New York City.
L. H. Taylor, Jr.,	Philadelphia, Pa.
Arthur G. Whipple,	Melbourne, Victoria, Australia.
Arthur G. B. Wilbraham,	Freiberg, Saxony.
William Q. Wright,	San José, Cal.

Associates made Members.

A. Forsyth,	Rapid City, So. Dakota.
William C. Siderfin,	Butte, Mont.

Members, Associates and Guests Registered.

The following list comprises those persons who were registered at headquarters in the Palace Hotel, at San Francisco, together with some others who joined the Institute party at various points *en route*. But it is still far from complete, since it was impossible to record the names of all who, in the course of the wonderful journey of the representatives of the Institute on the Pacific Coast, shared their pleasure and contributed to their entertainment. It may be added that the names of the accompanying ladies are not given—an omission which, however justifiable by considerations of delicacy, leaves the list of masculine participants decidedly incomplete as an expression of the social pleasure of the occasion.

Albert Arents.
Lewis E. Aubury.
F. E. Bachman.
Charles Belshaw.
E. H. Benjamin.
W. P. Blake.
G. W. D. Blood.
F. W. Bradley.

E. Buckingham.
J. Cabot, Jr.
Andrew Carrigan.
C. L. Cory.
S. W. Cheyney.
A. D. Chidsey.
S. B Christy.
B. F Chynoweth.
Theo. B. Comstock.
W. F. Crane.
J. J. Crawford.
John F. Davis.
W. S. DeCamp.
Philip Deidesheimer.
Charles C. Derby.
W. A. Doble.
James Douglas.
J. E. Douglas.
J. S. Douglas.
W. F. Downs.
Andrew P. Dron.
E. T. Dumble.
Theodore Dwight.
J. K. Eveleth.
T. M. Eynon.
B. F. Fackenthal, Jr.
W. F. Ferrier.
Frank Fitzsimmons.
Ernst Flemming.
A. D. Foote.
E. L. Foucar.
R. T. Guernsey.
D. H. Hahn.
J. F. Holloran.
C. A. Hamilton.
Wm. H. Hamplin.
Abbot A. Hanks.
W. J. Harris.
Charles T. Hoffman.
A. C. Holly.
John G. Hopper.
Edmund Jüsson.
Mark B. Kerr.
W. S. Keyes.
E. B. Kimball.
G. A. Kornberg.
Herbert Lang.
Martin A. Lathrop.
A. C. Lawson.
Frank A. Leach.
John Lilly.
Curtis H. Lindley.
N. W. Lord.
Edwin Ludlow.
W. H. McClintock.
W. H. McCord.
William McIlvain.
J. H. Means.
William P. Miller, Jr.
F. P. Mills.
O. Mühlhaeuser.
Thomas D. Murphy.
A. G. Myers.
J. H. Neff.
J. F. Newsom.
R. H. Norton.
W. G. Parke.
E. W. Parker.
Joseph W. Pinder.
John D. Pope, Jr.
Harold T. Power.
E. B. Preston.
Thomas Price.
William H. Radford.
W. C. Ralston.
T. D. Rand.
R. W. Raymond.
S. M. Richardson.
William H. Richmond.
L. D. Ricketts.
K. Riensberg.
Heinrich Ries.
D. M. Riordan.
T. Robins, Jr.
Irving M. Scott.
Richard C. Shaw.
A. W. Sheafer.
Ernest H. Simonds.
James Spiers, Jr.
Robert Stevenson.
W. H. Storms.
A. Thies.
Samuel Thomas.
R. C. Turner.
E. C. Voorhies.
Luther Wagoner.
J. P. Wallace.
A. A. Watkins.
J. R. Watson.
W. H. Wells.
A. E. Wheeler.
David Williams.
F. W. Wilmans.
Alan Wood, 3d.
A. B. Wood.
Louis T. Wright.
W. Q. Wright.
Charles G. Yale.

Excursions and Entertainments.

The preparation, even in outline, of an account of the well-nigh innumerable and indescribable excursions and entertainments connected with this memorable meeting proved to be so great an undertaking that the Secretary found himself obliged to reserve it for a later pamphlet, in order not to delay too long the issue of the official report of proceedings. The history of the Institute presents no precedent for the overwhelming abundance of hospitality, the wealth and variety of interest, and the perpetual keenness of enjoyment, characterizing the experience of those who were so fortunate as to take part in the California meeting and its excursions. It is not probable that such an experience will be repeated. There are no other *such* regions to be traversed; or, if such regions do exist, they are not inhabited by individuals and communities equally cordial and lavish in hospitality.

The Secretary's account of these excursions and entertainments, issued in pamphlet-form under the title "Proceedings of the California Meeting, Continued," is here reprinted, as follows:

It is not practicable to give more than a sketch of the numerous and varied excursions and entertainments connected with the California meeting; and even that sketch must needs be incomplete, since it was impossible, in the continuous excitement and distraction of the festive and professional attractions pressed upon the members of the Institute, to record fully all their particulars, or even the names of those persons, official boards, firms and corporations whose generous activity contributed to the multifarious and magnificent whole.

The acceptance by the Council of the invitation of the California Miners' Association to hold the autumn meeting at San Francisco was announced to members by the Secretary's Circular No. 2 of 1899, issued in April; and Circular No. 3, issued in June, called for the names of members expecting to attend the meeting. Affirmative replies to the latter circular were so numerous as to warrant the conclusion that at least 150 persons would go from points east of, and including, Chicago; and an excursion party was accordingly planned, to keep for the round trip, beginning and ending at Chicago, a special train of Wagner palace-cars, with dining-car, baggage-car, etc. The

expense of this train, including railway-fares and meals, and a side-trip to the Yosemite Valley, was estimated at $225 per passenger. This very low rate was made possible by the liberality of the railroad companies west of Chicago, four of which (the Great Northern, the Montana Central, the Northern Pacific and the Arizona and Southeastern) hauled the special train over their lines without charge, while the rest (the Chicago and Northwestern, the Southern Pacific, the Maricopa and Phœnix and Salt River, the Santa Fe, Prescott and Phœnix, the Santa Fe Pacific and the Atchison, Topeka and Santa Fe) accepted a nominal price per train-mile, scarcely covering, if, indeed, it did cover, the cost of the service. Exceptional favors were also granted by the New York Central and Hudson River railroad, and by the Oregon railroad and Navigation Company, operating the steamers on the Columbia river; and to the personal courtesy of Mr. Marvin Hughitt, President of the Chicago and Northwestern railway, the party was indebted for the great convenience of a baggage-car, put at its disposal for the whole trip. The travelers thus had access at all times to their trunks —a matter of serious importance upon a journey of such length, involving frequent changes of climate, for which it would have been difficult to provide in the hand-baggage carried in the sleepers. This favor is the more to be emphasized, because it was granted at a time of unprecedented pressure for rolling-stock upon all the Western railroads. The same consideration enhances the obligations of the party to all the railroad-companies above mentioned. The extraordinary increase of the regular passenger- and freight-traffic (which, coming after a period of light business and enforced economy, found most American railways unprepared with adequate facilities) rendered the arrangement of time-schedules and the provision of locomotives and crews for this special train a matter of extreme difficulty and annoyance; and the courtesy with which these services were rendered by the railroad-companies demands, under the circumstances, double recognition.

It is a circumstance worthy of note, as part of the history of the recent revival of trade in the United States, that the responses of members to the circular of June, above-mentioned, frequently contained the qualifying clause, that "if times were not too bad," they expected to take part in this trip. But as

the time approached, their tone changed, until the final burden, in many cases, was, that "times being so good," the writers could not possibly leave their posts! On this account, in fact, the anticipated number of the party dwindled to about sixty.

It was not expected that this party would be officially received at points on the way to California; but the announcement of its route called forth from members and others at Great Falls, Butte and Anaconda, in Montana; at Spokane, Washington; and Portland, Oregon, invitations, amounting in earnestness to demands, which could not be refused; and consequently arrangements were made for brief stops at these places. In like manner, after leaving the State of California, homeward-bound, the party was entertained at Bisbee, Phœnix, Prescott and Flagstaff, in Arizona.

The numerous and extensive excursions and entertainments in California were provided and arranged by the California Miners' Association, and included not only the special party above described, but also a large number of other members and guests, for whom the Association provided special cars, and the Southern Pacific Co. issued "souvenir tickets" for transportation. Indeed, the California Miners' Association, as host of the Institute, on this occasion, practically fulfilled the notice given beforehand by its genial Secretary, Mr. E. H. B[illegible], to the Secretary of the Institute, that "the visiting members might put away their pocket-books on crossing the State line, as they would not need them in California." That this fulfillment was not literal is due to the fact that, once in the Golden State, individual members were not to be restrained from independent expenditures of various sorts, principally for photographs, curiosities in "Chinatown," etc., and sometimes for eccentric departures from prescribed routes and programmes in the way of visits to special localities. But these exceptions only served to bring out in stronger light the indefatigable zeal and patience, and the admirable executive efficiency, of the committees officially representing the unlimited hospitality of the Miners' Association, which arranged in all such cases for the free transportation of the parties, and for their guidance and comfort.

As a sort of guide-book for this excursion, the paper by President Douglas on "Transcontinental Railway-Lines," with an appended Geological Railway-Guide, prepared by the Secretary,

and enabling the travelers to recognize, at each point, the geology of the region through which they were passing, was distributed on the train. Dr. Douglas's paper was subsequently printed for the *Transactions* (see p. 782), without the "Geological Railway-Guide," the latter having only a local and temporary value. It is, however, proper to acknowledge here the courtesy of Messrs. D. Appleton & Co., of New York City, for the permission to use, in the compilation of this guide, the material contained in Macfarlane's *American Geological Railway-Guide*, a work originally prepared, twenty years ago, by Mr. James Macfarlane, a member of the Institute, and republished in 1890, revised and largely augmented, by his son.

With the foregoing explanation, the series of receptions, etc., experienced by the special excursion-party outside of California, and by the larger party of visiting members and guests within that State, will be sketched in chronological order.

On Friday, September 15th, a portion of the excursion-party left New York at 1 P.M., in two Wagner cars, the "Convoy" (used throughout the trip as the headquarters-car, and accommodating the officers of the Institute, with reception-room, business office, etc.) and the "Escort," which were attached to the "Boston and Chicago Special" train for Chicago, *via* the New York Central and Hudson River and Lake Shore railroads.

On Saturday, September 16th, at 5.30 P.M., the special train, made up of the two cars mentioned, together with the "Wildwood," the "Maine" (for the accommodation of porters and other attendants), a dining-car and a baggage-car, left Chicago by the Chicago and Northwestern Railway, for St. Paul, Minn.

On September 17th the special train left St. Paul by the Great Northern Railway, several hours behind time, on account of unexpected difficulties in getting "a clear track." (These difficulties are peculiarly great for the single-track roads when they are, as at this time, almost choked with freight-business.)

Great Falls, Montana.

On September 18th the train reached Great Falls, Montana, but by reason of the delay in leaving St. Paul, and of loss of time *en route*, Great Falls was not reached until night, instead of mid-day, as the schedule had provided. This necessi-

tated a change in the programme of the local Reception Committee.*

A banquet, arranged as a part of the reception, had to be abandoned. But, through the skilfully improvised arrangements of the committee, the party was enabled to see the Black Eagle and Rainbow falls of the Missouri (which, under the fortunate co-operation of a full moon, were specially picturesque), the "Giant Spring,"† near the works of the American Smelting and Refining Co.,‡ and the smelting and electrolytic works and power-house of the Boston and Montana Consolidated Copper and Silver Mining Co.§

Among the points of interest, in and near Great Falls, which it was impossible for the party to visit, are the great falls of the Missouri (several miles below the Rainbow fall), the silver- and lead-mines of the Neihart and Barker districts, in the Belt mountains (a day's journey southeastward), and the coal-mines, washers and coke-ovens of the Anaconda Copper

* *Great Falls Reception Committee:* Hon. J. A. Collins, Mayor, Hon. Paris Gibson, Dr. J. A. Sweat, Hon. J. B. Leslie, Andrew Rinker, W. G. Conrad, S. E. Atkinson, O. F. Wadsworth, Jr., H. E. Byram, Ransom Cooper, A. J. Shores, A. E. Dickerman, H. O. Chowen, W. D. Dickenson, James T. Stanford, Dr. A. F. Longeway, J. T. Armington, W. P. Wren, R. S. Ford, P. J. Pheeney, E. T. Wright, Vincent Fortune, Gold T. Curtis, B. B. Kelly, W. M. Atkinson, Frank P. Atkinson, James O'Grady, Rev. E. A. Wasson, Daniel Tracy, P. O. Wels, R. L. Lloyd, J. T. Morrow, Willis T. Burns, W. J. Evans, O. S. Worden, E. H. Cooney, C. E. Wight, W. M. Bole, Phil. Gibson, H. B. Mitchell.

† This spring issues from the bank of the Missouri, some distance above the level of the river, as a stream of considerable size, the origin of which is not known. The theory that it is simply a part of the Missouri itself, which has left that river at some point higher in its course, and has returned to it, is said to be negatived by the chemical analyses of the two waters.

‡ These works, which rank among the most carefully planned and constructed of American lead-smelting establishments, were not running at the time of this visit, though they were expected soon to start. Mr. F. M. Smith, the local superintendent, kindly offered to conduct through the plant any persons desiring to inspect it; but on account of the lateness of the hour, this offer could not be accepted.

§ This establishment is perhaps the most complete and modern in America or the world, as regards especially the electrolytic refining of copper, for which power is obtained from the Black Eagle fall of the Missouri. The mines of the company are at Butte, Montana. The fact that these works were inspected at night added to their picturesque effect, while not diminishing their great professional interest. Indeed, the spectacle which they presented, superbly illuminated with innumerable electric lights, as viewed from the opposite bank of the Missouri, across the tumultuous Black Eagle fall, was a picture not soon to be forgotten.

Mining Co., at Belt, on the way to the last-named region. A number of the members of the party remained at Great Falls, and visited, next day, the coal-mines of the Sand Coulée Coal Co., on the line of the Great Northern road, where they enjoyed an excellent opportunity of inspecting the successful mining of coal by machinery.

Butte, Montana.

Leaving Great Falls after midnight, the party proceeded over the Montana Central Railroad to Butte, Montana, where it arrived on the morning of Sept. 19th. It is well known that, at this particular time, the leading mining companies of Butte are involved in bitter and complicated litigation, affecting the title to property of vast value. It is, therefore, matter for special notice and praise, that the representatives of all these conflicting interests united to give to the Institute party a cordial reception. So far as is known, all the mines and smelting-works were freely open to inspection by the party, though only a few could be visited. In the choice of these, and in the effective utilization of the limited time at disposal, the admirable arrangements of the local committee were essential aids.* Formal ceremonies were wisely omitted, and, with the exception of a luncheon served at the McDermott hotel, the day was wholly devoted to excursions of interest.

Anaconda, Montana.

Leaving Butte during the night, the party was conveyed to Anaconda, where September 20th was spent in the inspection of the great concentrating- and smelting-works of the Anaconda Copper Mining Co., under the guidance of Mayor Madden, Mr. T. K. Wilkinson, superintendent of the Anaconda refinery; Mr. J. S. Johnston, superintendent of the silver-mill; Mr. George Waddell, of the Company's engineering office, and Captain Kelly, superintendent of the smelters. Luncheon was served at the Montana hotel; and at 3 P.M. a special train was

* At a meeting of resident members and other representatives of Butte, Mr. John Gillie, Chairman, and Mr. F. L. Sizer, Secretary, were authorized to appoint an executive committee to arrange for the entertainment of the Institute party. The committee thus appointed consisted of Messrs. H. V. Winchell, G. H. Robinson, W. A. Akers, A. H. Withey and E. H. Wilson, and was actively assisted by Messrs. Gillie and Sizer, and by other Butte members.

run to Gregson Springs, ten miles from Anaconda, on the Butte, Anaconda and Pacific R. R., where a large number of the party enjoyed a refreshing hour.

Spokane, Washington.

At 11 P.M. the party left Anaconda via the Northern Pacific R. R. for Spokane, which was reached at 9.30 A.M. on Sept. 21st. A committee comprising Mayor Comstock, Mr. Storey Buck, Secretary of the Chamber of Commerce, and Messrs. W. N. Byers, N. B. Connelly, W. E. Hadley, J. E. Foster and Col. N. E. Lindsley, received the guests of the city, and escorted them upon a delightful ride in special trolley-cars through the business streets and picturesque suburbs of the city—Ross Park and Natatorium Park. At the latter place an open-air luncheon was served, and on the way a stop was made upon the bridge which spans the gorge of Spokane river, just below the falls, affording a striking view of their natural beauty, as well as the utilization of their mechanical power. Some of the party visited the mills for a closer inspection.

As a souvenir of this occasion, copies of an elegantly illustrated pamphlet, issued by the Spokane *Spokesman-Review*, under the fanciful title "A Million-Dollar Check, and Other True Treasure-Tales," were distributed to the visitors.*

The Columbia River.

At 6 P.M. the excursion left Spokane for the Dalles of the Columbia, where, on the morning of Sept. 22d, the river-steamer was taken for Portland. This impromptu variation of the schedule (which had originally contemplated a run by rail from Spokane to Portland) turned out a great success, embracing the elements of surprise to enhance its enjoyment. The day was perfectly clear and bright (a favorable wind having removed the haze from distant forest-fires, which so often obscures at this season the scenery of Washington and Oregon); and the majestic beauty of the grandest of American rivers was impres-

* This pamphlet describes the city of Spokane and the mining districts commercially tributary to it in Washington, Idaho and British Columbia. The million-dollar (strictly, $1,042,054) check, of which a fac-simile is given, was drawn on the Bank of Montreal by Lt. Gov. C. H. Mackintosh, of the Northwest Territory of Canada, in part payment for the Le Roi and other mines in British Columbia.

sively revealed and emphasized. From time to time the snowy splendor of Mt. Hood overtopped the forest-covered southern bank; and glimpses were gained of the summits of Mts. Adams, St. Helen's and Rainier, far to the north.

Portland, Oregon.

At the mouth of the Willamette river, the steamer was boarded by a welcoming delegation from the Portland Chamber of Commerce;* and, on reaching Portland, late in the afternoon, the party was conveyed in trolley-cars to interesting parts of the city and suburbs, including the heights from which a panorama of the harbor and river, as well as the city itself, could be seen in sunset-light. This picture of combined natural beauty and commercial progress fitly closed a memorable day.

Leaving Portland in the evening of September 22d, the party was conveyed by the Southern Pacific railroad through the Willamette valley and the mountain passes of southern Oregon and northern California to the picturesque Shasta Springs, where it arrived in the evening of Saturday, September 23d. During the afternoon the towering peak of Mt. Shasta, clad in snow, was magnificently displayed.

Keswick, California.

Near the California State line the party was joined by a carload of California friends, who had come from San Francisco as heralds of hospitality. The company thus augmented spent the night near Castle Crag, and early on the morning of September 24th proceeded to Keswick. Here it was met by the representatives of the Mountain Copper Co.,† and conveyed in a gaily

* The names of this delegation were unfortunately not preserved. The officers of the Portland Chamber of Commerce are: Charles F. Beebe, President; George Taylor, Jr., Vice-President; D. D. Oliphant, Secretary; E. C. Masten, Assistant Secretary.

† Messrs. Lewis T. Wright, general manager; H. B. Edwards, assistant manager; C. F. Archer, mine-superintendent; F. Monroe, assistant superintendent; J. W. Bennie, superintendent of smelting; D. A. Connolly, assistant superintendent; W. L. Cole, superintendent of railroad; and Walter Roundtree, James J. Murray, W. D. Fitzmaurice, H. P. Mendel, C. W. Renwick, H. L. King, B. C. Atkins, W. Temple, H. R. Roberts, J. Terry Seward, F. Davis, H. D. Campbell, John A. Clow, George Bridge, A. Donald, B. Hooper, A. Bill, A. H. Kingsback, A. McDonald, T. W. G. Wallace and C. Pollom, comprising the general staff in the chemical, assaying, financial and commercial departments.

decorated train of open cars up the narrow-gauge railroad of the Company* to the smelting works, where a stop was made for the inspection of the furnaces, etc., and thence, past the great series of roasting-heaps (which contain some 200,000 tons of ore in various stages of preparatory calcination) to the mines near the summit of the mountain. Here some of the party were conducted underground, while the rest enjoyed a welcome repose after the heat of the picturesque and impressive ascent.†

At 1.30 P.M. luncheon was served to the party in the main mess-hall of the miners, which had been transformed by lavish and tasteful decorations into a splendid banquet-hall. The British and American flags, with a bewildering abundance of ferns, flowers, fruits and electric lights, were the elements of a brilliant general effect, to which the festive company added the final touch. An interesting and suggestive feature of the decoration was a trophy, combining a pick and shovel, with a windlass-rope, artistically arranged about the illuminated figures "1849," as a symbol of the crude and simple mining of the pioneers; while, in contrast with these, a machine-drill, looking like a piece of modern artillery, and surmounted by the date "1899," told the whole story of the progress of half a century. The variety and excellence of the *menu* furnished as much surprise as satisfaction to the guests of the occasion, and constituted in itself a striking exhibit of the wonderful change which human enterprise has wrought in the rapid conquest of a continent. That a refined assembly of guests should be

* For the first 1½ mile, from the main line of the Southern Pacific, on the Sacramento river, to the smelting-works, 620 feet above tide, a third rail permits the hauling of broad-gauge cars into the smelter-yards. Beyond this point, for a distance of 12 miles (5 miles in an air-line), with a maximum grade of 200 feet to the mile, the narrow-gauge line ascends the "Iron Mountain" to the mines, 2000 feet above the smelting-works, heading the cañons, tunneling the intervening ridges, and climbing along the precipitous slopes, and in one place crossing itself in a "loop." A description of this road, and of the mines and smelters, by Mr. M. M. O'Shaughnessy, is given in "California Mines and Minerals," the souvenir volume published by the California Miners' Association in connection with this meeting. The Mountain Copper Co., Limited, is an English corporation which acquired in January, 1897, together with these mines, the New Jersey Metal Refining Works, at Elizabeth, N. J.

† The thermometer registered 108.5° F. "in the shade;" and although, as Californians are never weary of observing, such temperatures, being "dry heat," are not nearly so oppressive as much lower ones in the Eastern States, it was admitted to be "more than hot enough for all practical purposes."

gathered to partake, in the heart of yesterday's untrodden wilderness, of an entertainment worthy of the luxurious taste of the oldest civilizations, was a marvel, epitomizing the new age of miracles. And the further circumstance that the hosts of the occasion represented a company of men in a foreign land, who had never seen their guests, and who could not expect from their hospitality any reward beyond fraternal recognition, emphasized the deepest effect of modern progress, namely, the union of nations for the ends of a common welfare. By a happy thought of President Douglas, the occasion fitly ended with the singing by the whole assembly of a verse of "America," and a verse of "God Save the Queen." Nothing could more compactly express the cordial relations of the two peoples who sing their national anthems, in different but not conflicting words, to the same tune!

Redding, California.

Returning to the special train at 6 P.M., the party proceeded to Redding, 12 miles distant, where it was entertained at another banquet—almost a surfeit of hospitality for one day. Mr. M. E. Dittmar, as the representative of the Local Committee, welcomed the guests; Col. C. A. Garter presided; and addresses were made by Lieut.-Gov. J. H. Neff, Judge Edward Sweeney, Gen. W. D. Tillotson, and Mr. Charles G. Gale. This banquet, though late and brief, was significant as the expression of the welcome of Northern California to the representatives of the professions and industries to which that part of the State (possessing great mineral resources, as yet comparatively undeveloped) looks for aid and stimulus in the future.

At a late hour the special train left Redding for San Francisco, and the excursionists, crossing the ferry from Oakland, arrived at the Palace Hotel on Monday, September 25th, at about 10 o'clock A.M., in time to settle themselves comfortably and prepare for the opening session of the meeting, at 1.30 P.M.

San Francisco.

No general excursions were arranged in San Francisco or its vicinity which would interfere with the regular sessions of the meeting; but numerous works, exhibitions, clubs, and other places of interest were freely opened to the Institute, and were visited by its members and guests as opportunity offered.

The ladies of the party were entertained in the afternoon of Tuesday, Sept. 26th, by the California Women's Club (Mrs. Lovell White, President).

The San Francisco Local Committee maintained at the Palace Hotel a headquarters for registry, information and general assistance and guidance, which greatly facilitated the satisfaction, by individual members and guests, of their several preferences in the way of optional local excursions.

In this category the following may be mentioned, rather as specimens than as a complete catalogue:

The Exhibit of the State Mining Bureau; the Mechanics' Fair;* the Cliff House, Seal Rocks and Sutro Heights; Mount Tamalpais; the Golden Gate Park and its museum; the U. S. Mint; the Hopkins Art Institute; the California Pioneers' Museum; the California Academy of Sciences, and the Clubs of the city.

This list, however, does not adequately represent the hospitality of San Francisco. The truth is, that [illegible] everywhere, was opened with overflowing hospitality to the members and guests of the Institute.

The University of California.

On Wednesday, Sept. 27th, at 12.30 P.M., the Institute party left San Francisco by the Oakland ferry for a visit to the University of California at Berkeley, where it arrived at 1.30 P.M., and inspected with great interest and pleasure the grounds, buildings, laboratories, museums and equipment of this already famous institution.†

The Selby Smelting-Works.

From Berkeley, the party was [illegible] by special train to the Selby smelting-works, near Vallejo junction, one of the

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* Where the prize plans for the future buildings of the University of California were displayed.

† Some notion of the extent and completeness of one department of the University of California may be gathered from the following list of the faculty of the College of Mining:

Benjamin Ide Wheeler, *President;* Samuel B. Christy, *Dean, and Professor of Mining and Metallurgy;* F. G. Hesse, *Professor of Mechanical Engineering;* Joseph Le Conte, *Professor of Geology;* Willard B. Rising, *Professor of Chemistry;* Frederick Slate, *Professor of Physics;* Frank Soulé, *Professor of Civil Engineering;* Irving Stringham, *Professor of Mathematics;* and seven associate and assistant professors, together with more than twenty-five instructors and assistants, in the above departments.

oldest, and still the most important of the metallurgical establishments of the Pacific coast. After inspecting the furnaces and other apparatus of these works, the party returned to San Francisco.

The San Francisco Banquet.

On Wednesday evening a banquet was given to the visiting members and guests of the Institute at the Palace Hotel, by the merchants of San Francisco. Mr. A. A. Watkins, President of the Board of Trade, presided, and speeches were made by Mr. John J. Davis of Amador, Mr. Irving M. Scott of San Francisco, President David Starr Jordan of the Stanford University, Prof. S. B. Christy of the University of California, and others.

The Leland Stanford, Jr., University.

At 8.30 A.M., Thursday, Sept. 28th, the special train left San Francisco by the Monterey line of the Coast Division of the Southern Pacific railroad, reaching at 9.45 the station of Palo Alto, where numerous carriages were in waiting to convey the visitors to the grounds and buildings of the Stanford University, and the Stanford stock-farm. The scenic and architectural beauty and the admirable educational plant of the University were highly admired; while the stock-farm, aside from its exhibit of splendid horses, possessed a peculiar interest by reason of the fact that, during the dark days of the University, when litigation had locked up, and threatened to confiscate, the whole of its magnificent endowment, the sale of stock from this farm furnished a part of the money for necessary running expenses. The story of the manner in which the remainder was raised, by the greatest sacrifices on the part of Mrs. Gov. Stanford, the faculty of the University, and its students and friends, is a wonderful record of faith, loyalty and devotion; and no one who knows it can fail to rejoice that the University, thus tested by severest trial, having emerged from the ordeal unscathed and unstained, has now come into its own, and has resumed its rank as one of the most richly endowed institutions of learning in the world,* while the struggle for life through which it has passed has produced in its students and faculty an *esprit de corps* as strong as if supported by the traditions of a century.

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* The endowment is said to exceed $20,0C0,000.

San José.

Returning to Palo Alto, the party proceeded to San José, where luncheon was served at the Hotel Vendome. Some remained in San José during the afternoon, driving about the city and viewing the beautiful streets, residences and fruit-orchards. The larger number left San José in carriages at 2 P.M., and drove 28 miles across the valley and up the side of Mt. Hamilton, to the Lick Observatory, where they were cordially entertained by Director James E. Keeler and his corps of associates and assistants.*

After supper, the observatory was inspected; the tomb of James Lick, its founder, was visited; the starry heavens were viewed through the great 36-inch refractor-telescope; and at 10 P.M. the guests, bidding a reluctant farewell to their hospitable hosts and to the unique charms of the place, started upon the romantic night-journey down the smooth, winding

* Lick Observatory was founded by the late James Lick, one of the pioneers of California, who left by will $700,000 for the purchase of land and the erection of "a powerful telescope, superior to and more powerful than any telescope yet made . . . . and also a suitable observatory connected therewith," wisely providing that the income of any remaining surplus should be devoted to the maintenance thereof, "and shall be made useful in promoting science," and that the observatory should be a department of the University of California. The gift was accepted in 1875 by the Regents of the University.

The observatory now comprises a main building, covering computing-rooms, library, and the two main equatorial telescopes; detached buildings for other apparatus, dwelling-houses for astronomers, students and employees, work-shops, etc. The land amounts to about 2581 acres, of which 2030 acres have been granted by the United States, and 320 by the State of California, the remainder having been donated by individuals.

The apparatus comprises, besides the great Lick telescope (a 36-inch refracting equatorial, the objective of which was made by Alvin Clark & Sons), a 12-inch Clark equatorial, a 3-foot reflecting telescope (constructed by Dr. A. A. Common, F.R.S., and presented in 1895 by Edward Crossley, Esq., F.R.A.S., of Halifax, England), and a large number of smaller instruments (comet-seekers, photographic telescopes, spectroscopes, etc.).

The observatory is a school of astronomy for graduates of the University of California. Its officers, at the time of the visit here recorded, were: Benjamin I. Wheeler, *President of the University;* James E. Keeler, *Director and Astronomer;* William W. Campbell, *Astronomer;* R. H. Tucker, Jr., *Astronomer;* William J. Hussey, *Astronomer;* Charles D. Perrine, *Secretary and Assistant Astronomer;* Robert G. Aitken, *Assistant Astronomer;* William H. Wright, *Assistant Astronomer;* Edwin F. Coddington, *Fellow at Lick Observatory;* R. Tracy Crawford, *Fellow at Lick Observatory;* Harold K. Palmer, *Fellow at Lick Observatory.*

The tomb of James Lick is under the great telescope with which his name is associated.

"grade," along the sides of precipitous cañons, and across the valley to San José, where they arrived in the small hours of the morning.

New Almaden.

On Friday, September 29th, the Institute party was divided —a considerable minority taking carriages from San José at 8 A.M., and driving to the quicksilver-mines of New Almaden, 15 miles to the south. The charming scenery of the Coast range, traversed by this route, and of New Almaden itself; the generous welcome and entertainment furnished by the Quicksilver Company, as represented by Mr. Charles C. Derby, manager (a member of the Institute) and his associates; and the professional interest attaching to the inspection of these historic mines and of the most complete and perfect metallurgical plant in the world for the treatment of quicksilver-ores, combined to render this excursion exceptionally instructive and delightful; and the party returned to San José full of enthusiastic gratitude and burdened with magnificent specimens of cinnabar.

Del Monte.

Those of the party (including the ladies) who did not take the trip to New Almaden proceeded with the special train to Del Monte, the famous all-year resort of the Pacific coast, on the bay of Monterey. Here they enjoyed lunch and dinner at the great hotel, and, between the two, inspected the uniquely beautiful grounds, visited the bathing-pavilion, and made the wonderful "17-mile drive" through the quaint old whaling port of Monterey, along the rocky coast and back by forest-roads. The day was perfect; the surf was magnificent; the bay was exquisitely blue; the seals and sea-birds were numerous and lively; curious marine treasures were cast upon the beach by wind and tide; and altogether the trip was a memorable one.

In the evening the special train, rejoined at San José by the New Almaden contingent, returned to Oakland Pier, where another San Francisco party was added to it, and the augmented excursion continued to Colfax, arriving during the forenoon of Saturday, September 30th.

Grass Valley.

At Colfax the party was met by a reception committee, headed by Mayor C. E. Clinch, of Grass Valley, and was transferred

to a special train of the Nevada County railroad (narrow gauge), which generously placed at the service of the Institute not only the facilities of the road, but the cordial and indefatigable labors of its superintendent and officials. A ride of 17 miles, winding among the ravines and wooded crests of the spurs of the Sierra Nevada, brought the party to Grass Valley, after a brief visit to the Brunswick mine, in the outskirts of that town, where the electric hoist, 20-stamp-mill, etc., were examined with interest.

On the train, badges and souvenir-folders were distributed to the guests. Concerning the latter, it may be appropriate to say that long experience has shown no other variety of souvenir to be so acceptable and valuable to visiting members of the Institute as that which presents a succinct account of the district visited and its mineral industry, thus not only obviating the otherwise inevitable reiteration of elementary questions and patient answers, but also putting into the hands of visitors something which, treasured by them, will both vividly revive and accurately control their personal reminiscences. The Grass Valley souvenir answered this description, containing, as it did, an excellent topographical and geological map of the district, a brief sketch of its history, an outline of its metallurgical practice, and a list of its active mines and mills. As a record useful for the measurement of both past and future progress, the following statements have been condensed from this souvenir:

The discovery of the gold-placers of Grass Valley in 1849 was followed by that of gold-bearing quartz in place (on Gold Hill) one year later; and lode-mining for gold on the Pacific slope may be said to have originated here. The primitive hand-windlass and horse-whims were long ago superseded by steam-power, and this has now largely given way to water-power, electric-power and compressed air, variously combined. The present use of water- and electric-power is about equally divided (approximately 1700 horse-power of each). Both the Water Co. and the Electric Power Co. are said to have large reserves, which they furnish at an average price of $5 per horse-power per month. In many of the mines compressed air plants are driven by water or electric power. Water is supplied through three separate pipe-lines, under pressure up to 335 pounds per square inch, according to locality.

The veins are narrow (6 inches to 3 feet) and have an average dip of 35 degrees; and the rock is hard. But little heavy timbering, therefore, is required; yet the cost of mining is, of course, larger than on wider veins. In those instances which may be considered as showing the best results, the total cost of mining and smelting is less than $6 per ton.

The process of treatment employed is "free-milling." There are now 241 stamps in operation, crushing two tons each per day of ore yielding about $10 per ton as an average, with some exceptions of much higher grade. The sulphides (about 3 per cent. of the pulp) are saved by Frue vanners and canvas-covered tables, and are worth $50 to $150 per ton. The entire extraction varies from 90 to 93 per cent. of the assay-value, as determined by careful daily tests.

The following are the leading mining companies now at work; the number of stamps run by each being given in parenthesis: Empire Mining and Investment (40); North Star Mines (40); Maryland Mining (40); Grass Valley Exploration (20); Brunswick (20); Gold Hill (10); Omaha Consolidated (28); Bullion (10); Pennsylvania (10); Menlo (8); Electric (10); Granite Hill (5). The following companies may also be named as mining, though not running stamps of their own: Union Hill Consolidated; Golden Treasure; Jenny Lind; Conlin and Alison Ranch.

The city of Grass Valley has 8000 inhabitants, a complete electric-lighting plant, municipal water-works and a modern sewer-system.

Arriving at Grass Valley at about 1 P.M., the party was immediately conveyed in carriages to the Empire mine, where a delightful *al fresco* lunch was served under the trees in the grounds of the company, at which the guests of the occasion were waited upon with graceful courtesy by ladies of Grass Valley. Subsequently, under the guidance of Mr. W. B. Bourne, the principal owner of the mine, and Messrs. Starr (general manager) and Simmonds (superintendent), the hoist, stamp-mill, underground workings, etc., were inspected. This mine and plant present an exceptional combination of admirable technical convenience and efficiency with neat and tasteful outward appearance, constituting an object-lesson for those who fancy that the vicinity of a mine must necessarily be a scene of

barren waste and disorder. In another respect, also, the Empire is instructive, namely, as an instance of the restoration of prosperity to an enterprise (almost the oldest of its class in the State) which had been practically abandoned in despair by the majority of its owners, and was continued with undaunted courage and intelligent faith by one man, who now reaps the result of his persistent endeavor. Such instances of success in deeper mining are becoming more and more numerous in California, and constitute the basis of a new era in the mining industry of the State.

After leaving the Empire mine the party was divided, smaller portions visiting the W. Y. O. D., the Pennsylvania and the Massachusetts Hill mines, the power-house of the latter, etc. It goes without saying that they were everywhere received with overflowing hospitality; that the mines and plants, both above and underground, were freely opened to them; and that the limitations of time were the only obstacles to their complete inspection of all the mines of Grass Valley, many of which, where they would have been equally welcome, would have proved as interesting and instructive as those which they were able to see. In fact, some members of the party remained a day longer at Grass Valley, in order to avail themselves of this professionally valuable opportunity.

In the evening, at the Holbrooke House, a banquet was given to the Institute, at which Mayor Clinch presided, an address of welcome was made by Mr. W. A. Sleep, and responded to by President Douglas, and other addresses from hosts and guests contributed to the festive occasion.

Nevada City.

On October 1st the main portion of the party proceeded by special train on the Nevada County railroad, 6 miles, to Nevada City, where they were entertained by the town authorities,* and

* The following proclamation was published in the daily papers:

"Members of the American Institute of Mining Engineers, their ladies and visitors: The city of Nevada, through her Board of Trustees, bids you welcome, and extends to you the key of the freedom of the city to-day. We are glad to have your distinguished body honor the 'Queen City of the Sierras' and the county-seat of the county of Nevada, with your presence. We desire that you visit our great quartz- and drift-mines, knowing that it will mean pleasure and profit to all. The city is yours for this day.

"BOARD OF TRUSTEES,

"By B. S. RECTOR,

"*President.*"

by the representatives of the Providence and Champion mines, both of which were visited and inspected. The Providence mine has been worked almost continuously for 25 years past, and has yielded more than $5,000,000. The incline is now nearly 2000 feet long. There is a fine 40-stamp mill and an excellent chlorination-plant. The Champion, adjoining the Providence, is nearly as deep, and nearly $1,000,000 annually is produced from this mine and others near it, operated by the same company. Besides their eminence as producers, the Providence and Champion mines enjoy the distinction of having furnished occasion for one of the most important decisions of the U. S. Supreme Court under the Federal mining act.*

Many other promising quartz-mines, and the famous drift-mines along Washington ridge, where the ancient river channel is worked by drifting in the auriferous gravel, could not be visited for lack of time.

Dutch Flat.

Returning to Grass Valley, the party went on to Colfax, where it took again its broad-gauge special train, late at night, October 1st. On October 2d it proceeded to Dutch Flat, enjoying on the way the wild and picturesque scenery of the foothills and forests of the Sierra, scarred here and there with the great denudations produced by hydraulic mining. At Dutch Flat the Polar Star hydraulic mine was operated for an hour for the entertainment of the party.† Dynamite blasts were fired to loosen the cemented gravel; and two "Monitors" delivered their powerful streams against the bank, tearing away great masses of earth, pebbles and boulders, and carrying their

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* Walrath *vs.* Champion Co.

† At the present time, most of the hydraulic mines in this district are idle, by reason of the famous injunction issued by the Federal Court in the "débris cases." Some are allowed to operate, under a later *modus vivendi*, by permits, granted upon the fulfilment of certain conditions as to the impounding of tailings. The Polar Star, which has in an adjoining cañon a high dam, behind which its tailings are held, is one of these. But, at the time of this visit, the regular operation of this mine was suspended for another reason, namely, the scarcity of water, due to the exceptional drought following two years of scanty rainfall. As I understand it, the water-supply of the ditch upon which the mine relies was subject to prior rights of agricultural and other consumers, so that, in order not to disappoint the visiting representatives of the Institute, the owners of the Polar Star were obliged to purchase, by an extra payment, the privilege of using the water for a limited period, besides paying the water-company for it at the usual rates.—R. W. R.

auriferous burden into sluices. Photographs of the scene were taken for "kinetoscope" pictures, to be exhibited at the Paris Exposition of 1900.

Auburn.

The next stop was made at Auburn, where the party was cordially received by Mayor Morgan and a committee, conveyed in carriages to various points of scenic interest, and afterwards entertained at a lunch in the open air, at which Mr. F. P. Tuttle presided, and made an address of welcome. Auburn is not now characteristically a mining town, but rather the center of a thriving horticultural industry, which has planted itself upon the ruins of the early placer-mining of the foot-hills, and which made a striking exhibition of its results in the fruit, flowers and native wines displayed upon the tables of the feast spread for the guests of this occasion. The tenor of the speeches indicated a new era of harmonious co-operation, rather than hostility, between the two great industries represented, and a readiness on the part of each to recognize the importance of the other to the prosperity of the State.

Sacramento.

The Committee on Mines and Mining of the Sacramento Chamber of Commerce, Messrs. W. D. Lawton, A. C. Hinkson, John Weil, A. J. Bruner, and A. C. Herrick, joined the party at Auburn, and accompanied it to Sacramento, where, at 4 P.M., Oct. 2d, it was met by President Frank Miller and the directors of the Chamber, and conveyed by trolley to the Art Gallery of the Museum Association. Here President Woodson of the Association introduced Mayor Land, who officially welcomed the visitors to the city. After an appropriate reply by President Douglas, and a rapid inspection of the gallery (especially of its *chef-d'œuvre*, a magnificent picture of the Yosemite, by Hill), the trolley-ride was continued to Sutter's Fort, an interesting historic locality, restored and preserved by the Society of Native Sons of California as the scene of the first examination, testing and recognition of the specimen of gold brought to Gen. Sutter by Marshall. An interesting collection of relics, portraits, etc., connected with the days of "the Argonauts," was inspected; and several addresses were made, giving particulars of the test of Marshall's nugget by

Lieut. (afterwards Gen.) W. T. Sherman. An unexpected pleasure was furnished to both hosts and guests by the discovery that a member of the party, Mr. John Lilly of Lambertville, Pa. (Marshall's birthplace), had personally known the famous pioneer and his family, and had been the administrator of his estate. Mr. Lilly's account of Marshall's return after many years of absence was received with much interest.

During the visit to Sutter's Fort, two excellent photographs of the party were taken, from which Figs. 1 and 2 have been reproduced.*

From Sutter's Fort the party was conveyed to the Golden Eagle hotel for dinner, and in the evening it visited the Capitol, where it was received by the Governor and State officials, and spent a pleasant social hour in the handsome room of the State library. Here brief addresses were made by Mr. Frank Miller, President of the Chamber of Commerce, Secretary of State Curry, President Douglas, Dr. R. W. Raymond of New York, Prof N. W. Lord, of the Ohio State University, and Mr. D. M. Riordan, of Tucson, Arizona.†

* These pictures were taken by A. K. Varney, photographer, 418 K St., Sacramento, Cal., from whom copies can be obtained, at 50 cents each, by members of the party or others who may be interested. In the original photographs, the various members of the party can be clearly recognized—and some are included who have been cut out in the engraving, to accommodate the picture to the size of the page without undue reduction of scale.

† Prof. Lord's remarks expressed, from the standpoint of a representative of the higher education, a hearty recognition of the energy and wisdom with which California had not only developed material wealth, but, in its two magnificent universities and scores of other institutions for education and art, had provided for intellectual culture.

Dr. Raymond's remarks were devoted to a single feature in the history of Sacramento, the significance of which is deemed to justify their reproduction here. Dr. Raymond said, in substance:

"It is 31 years since I first saw Sacramento; but I had been proud of Sacramento long before I saw it. As a student in Germany, forty years ago, I knew an old German University professor, who had a profound faith in democracy and in geography, and who, believing in the American people and in the map of California, though he had never seen this continent, had selected Sacramento as a city destined to greatness, and had invested his modest savings in its 10 per cent. gold bonds. This was before the beginning, even, of the Pacific railroads; before, to the advantage of Sacramento, the Donner Lake route had been selected instead of the Placerville route; and before either the commercial prosperity or the financial honor of Sacramento had been demonstrated. Time passed on; the city was devastated by fire and flood; payment of interest on the bonds was temporarily suspended; at one period, if I remember correctly, the sheriff even levied on the

Oroville.

Leaving Sacramento late at night, the party proceeded to Oroville, where on Tuesday, October 3d, the drift and quartz-mines, and the dredgers at work in and near the Feather river, were inspected with great interest and satisfaction. Six dredgers are now working at Oroville, and two more are under construction. Some of these machines have a capacity of 2000 cubic yards daily, in reasonably soft ground, or 800 to 1000 yards in hard ground. The cost of dredging ranges from 3 to 6 cents per cubic yard. This new industry, avoiding the difficulties encountered by hydraulic mining in the disposal of *débris*, and permitting a close preliminary test of the value of the ground to be worked, is said to be peculiarly safe as an investment, and, though limited in its field, will doubtless add much to the gold-product of California. For interesting details concerning it, the souvenir volume, "California Mines and Minerals," already mentioned, may be consulted.

The Oroville region presents a picture not only of a still active mining industry, but also of the prosperous horticulture which, favored by the wonderful climate of the foot-hills, has grown up amid the ruins of the early gold-diggings. This feature was beautifully shown by the abundance of flowers and fruits which adorned the banquet given to the Institute party, and loaded to overflowing the special train, upon its departure, in the evening of an intensely interesting and delightful day.

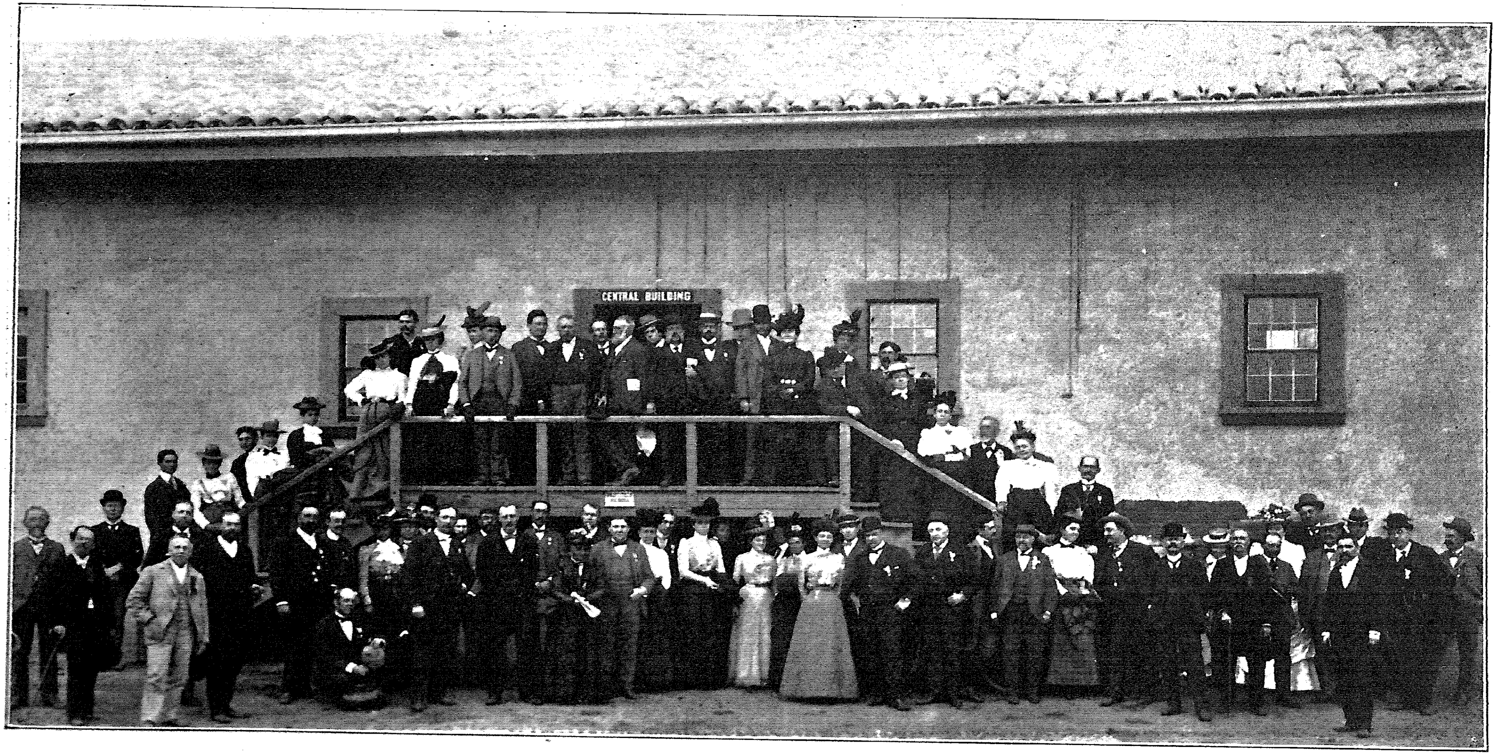
The Mother Lode.

Early in the morning of Wednesday, October 4th, the party, leaving the railroad at Ione, was conveyed in carriages, in three

furniture in the City Hall; but my old friend never lost faith in the people and the map. And, sure enough, Sacramento rose again from her mud and her ashes, and redeemed to the last dollar her municipal obligations; and my old friend reaped the reward of his unconquerable confidence, while his prudent, conservative friends, who had shaken their heads over his wild investment in a distant land and his reckless faith in a democratic commonwealth, regarded him with envy as a successful capitalist. When we talk of 'capitalists,' we may as well remember that most of them are simple, humble, thrifty folk, who trust their fellow-men. And in these days of specious repudiation, when the fact that a man has lent us money is deemed sufficient ground for denouncing him; when the hardships of debtors are paraded as their wrongs, it is refreshing still to find instances of the righteous man, described in the Good Book, who 'keeps his promise to his hurt,' and of citizens who hold that what they would deem honest in their private deal-

Institute Party at Sutter's Fort, Sacramento, Cal., with Old Overland Stage-Coach and "Prairie-Schooner" in the Background.

Fig. 2.



Institute Party at Sutter's Fort, Sacramento, Cal. The Building in the Background is the one shown on the Right in Fig. 1.

divisions, to Amador City, Sutter Creek and Jackson, respectively, as guests of the Mining Associations of Amador and Calaveras counties. Each division was enabled to visit various mines, and was entertained for the night at one of the three towns named. A convenient and elegant programme, containing a map of the Mother Lode from Jackson to Plymouth, was presented to each visitor. The rest of the day was spent in examining prominent mines in this part of the Mother Lode, including the Keystone, Kennedy, Argonaut, and several others, which illustrated most forcibly the remarkable renaissance of lode-mining in this historic belt, and the essential factors of this renewed prosperity, such as the reduction of the cost of mining and milling by the use of water-power, improved machinery, and more careful business management; the consequent ability to mine and treat with profit large masses of low-grade ore, formerly rated as equivalent, economically, to barren rock; and the encouragement given by these favorable conditions to explorations in depth, which have been rewarded by the discovery of valuable ore-bodies, promising an indefinite continuance of profitable mining.

On Thursday, October 5th, the party drove to the celebrated Gwin mine, in Calaveras county. This mine may be cited as a conspicuous instance of the new era in the development of the Mother Lode. Once a famous bonanza, then abandoned as exhausted, and lying idle for many years, it was reopened in 1894, and is now one of the regularly productive gold-mines of California, having a continuous ore-body 1500 feet long on its 1400-foot level, and supplying 80 (soon to be 100) stamps with 5 tons of ore per stamp daily,—everything between the walls of the lode (which averages more than 10.5 feet in width) being sent to the mill. Further particulars concerning this in-

ings is also honest in municipal affairs. No doubt, in the long history of the payment of the debt of Sacramento, there have been many to protest against the sacrifices involved. And, no doubt, on sentimental grounds, much may be said regarding the severity of the burdens imposed by a former generation upon those who, under new conditions, have succeeded involuntarily to the heavy responsibility. But I, for one, rejoice profoundly when, in spite of all casuistry, the citizens of a great city bravely resolve that a promise must be kept. This is what Sacramento has done: it has put honor above gold; it has hoisted and kept flying the banner of stainless municipal integrity. Not all the gold that spangles the valleys or ribs the mountains of California is worth as much as such an act:—and that is why I am proud of Sacramento!"

teresting enterprise will be found in the souvenir volume on "California Mines and Minerals," already repeatedly cited.

The new mill-building of the company (not yet in daily operation) was transformed, by lavish decorations of flags and garlands, into a magnificent banquet-hall, in which an elaborate and elegant luncheon was spread, as the farewell of the Mother Lode to the Institute party. An admirable orchestra discoursed exquisite music; the workmen of the mine and mill, aided by a large number of ladies, masquerading as attendants, exhibited no less skill, and much greater cordiality, than "professionals" could have commanded, and the *menu* was metropolitan. Appropriate addresses were made by Hon. F. J. Solinsky, formerly District Attorney of Calaveras county, Mr. F. F. Thomas, General Manager of the Gwin mine, Mr. David McClure, Superintendent of the mine, and many others; Mr. E. W. Parker, of the U. S. Geological Survey, replying for the Institute.

From the Gwin mine the party was conveyed to Valley Springs, and thence by narrow-gauge special train to Lodi, where its own broad-gauge special train was waiting to carry it to Raymond, the station at the end of the branch railway, connected by stage-line with the Yosemite Valley. This involved the abandonment of a part of the arranged programme, namely, a visit to Jamestown and Sonora, and the gold-mines of the Mother Lode in Tuolumne county. This county presents a considerable number of active mines, supplying, when in full operation, 698 stamps* with ore extracted, in several instances, from depths between 1000 and 1700 feet; and thus offers a striking additional illustration of the new era in California quartz-mining, exemplified, as already described, in Amador and Calaveras counties. Unfortunately, at the time of this visit, nearly if not quite all of the mines and mills of Tuolumne county had been shut down by reason of the lack of water due to the exceptional drought of two successive years; and it was deemed unfair, both to the local mining interests and to their invited guests, that the region should be inspected under cir-

* Of which 330 are run upon ore from mines on the Mother Lode, and 368 are on the so-called East Belt, in the granite to the east of the slates in which the Mother Lode occurs. These figures are taken from the souvenir volume, "California Mines and Minerals."

cumstances so unfavorable to a just appreciation of its mineral resources and industry. This part of the trip, therefore, was omitted with much regret on both sides.

The Yosemite Valley.

Arriving at Raymond early in the morning of Friday, October 6th, the party left the special train and proceeded by stage to Wawona (where the night was spent), and to the Yosemite Valley, which was reached Saturday afternoon, October 7th. Sunday was spent in and about the Valley; on Monday Glacier Point was visited, and Wawona was reached for the night's lodging; on Tuesday a trip was made to the Mariposa grove of "Big Trees;" and the excursionists, arriving in the evening of that day at Raymond, resumed their special train, which delivered them safely, Wednesday forenoon, at Los Angeles.

This itinerary necessitated another regrettable sacrifice, namely, that of the projected alternative trip to the great vineyard and raisin district of Fresno, the oil-regions of Coalinga and Santa Paula, the largest beet-sugar factory of the world, at Oxnard, and the charming scenery of Santa Barbara. Since nearly all of the visitors from the East desired to visit the Yosemite, there were not enough of those who did not take that excursion to constitute a formal party for the alternative provided by the superabundant hospitality of California. Not a few members, nevertheless, who had been in the Yosemite already, availed themselves of the opportunity to visit different parts of Southern California. At Los Angeles all these travelers (jocosely designated as the "Anti-Semites," to distinguish them from the "Yo-Semites") rejoined the main body.

Los Angeles.

The brief but highly interesting and agreeable entertainment of the party at Los Angeles was superintended by Mayor Fred. Eaton, and representatives of the Chamber of Commerce (Theo. B. Comstock, H. Z. Osborne and John D. Pope, Jr.), the Miners' Association of California (Alfred Solano, U. S. G. Todd and J. J. Gosper), and the Engineers' and Architects' Association (Edgar L. Swain, James W. Warren and A. M. Edelman).

The guests were taken, upon their arrival, into special trolley-

cars, and conveyed through the principal streets of the city, including brief visits to Hollenbeck Park and to the oil-field, which, with its forest of derricks, has encroached already into a part of the residence-district. At an informal reception at the Chamber of Commerce, which followed, addresses of welcome were made, and Prof. W. L. Watts gave a brief but clear account of the Los Angeles petroleum-deposits.* The collective exhibit of native products contained in the rooms of the Chamber of Commerce was inspected with much interest. Luncheon was served at the Van Nuys hotel annex; and the afternoon was spent in various excursions to Santa Monica, Pasadena, the ostrich farm, etc. For the evening a theatre-party, organized by the Engineers' and Architects' Association, was followed by a supper at Levy's, where the *menu* consisted almost wholly of Mexican dishes, to which many of the visitors were strangers.

On the following morning a considerable party of early-risers made a trip by special train to the top of Mt. Lowe, one of the most beautiful peaks on the coast, with an astronomical observatory half-way up the mountain. This party returned, full of enthusiastic reports of its doings, in time to join the regular special train at Pasadena, *en route* for San Diego.

San Diego.

After a delightful journey along the coast, the party arrived at San Diego about sundown on the evening of Thursday, October 12th. They were received at the railway station by a Local Committee, headed by Mayor Capps; but in view of the lateness of the hour, no formal reception was attempted. Some of the party drove off in carriages to see what they could of the city and its suburbs; the rest were taken at once by ferry to the Coronado hotel, where they arrived just in time to view from the beach the last glories of a magnificent sunset over the Pacific Ocean. The evening and night were spent at this famous resort, the picturesque beauty of which is too well known to need description here; and early the next morning the party left with regret the Coronado and San Diego. It should be added that this swift, short visit was not planned with the idea that San Diego and its vicinity constituted only what theatrical people

* This will be published separately, as a paper in the *Transactions*.

call a "one-night stand." It was a sudden afterthought, introduced into the programme to gratify those who had never seen the place, and to whom a fleeting vision of its beauty would be ever so much better than nothing.

Riverside and Redlands.

On Friday, October 13th, under the guidance of Mr. Lewis E. Aubury, of Los Angeles, who, as the representative of the General Executive and Excursion Committee of the California Miners' Association, accompanied the party through Southern California, the homeward journey was begun; and on this day was encountered the first and only thorough disappointment in the whole series of visits. True, certain parts of the original programme had been abandoned, as has been noted above. Tuolumne county was not visited, and the optional side-trip to Fresno, etc., was not taken, for reasons already set forth in both these instances. But this unlucky Friday was the only day on which the party actually reached a place and could not see it! Namely, it was intended to traverse "the loop" of the railway, so as to see something of the marvellous floral and horticultural wealth of Southern California, before striking at Colton the main line of the Southern Pacific, for the eastward journey. And the hospitable gardeners and vintners of the region had planned to take their visitors from the train at Cresta Blanca, and carry them through the bewildering sub-tropical splendors of "Magnolia Avenue" (ten miles long) to Riverside, while the train pursued the more prosaic line of the railway-track to the same point. Further entertainment at Redlands was prepared, and flowers and fruit enough to smother and gorge the party had been provided. Although, like nearly all of the Southern California programmes, this plan had been hastily arranged as a supplement to the original programme of the Miners' Association, it promised a day of exceptional enjoyment. But alas! it was thwarted by a cause which Californians are not accustomed to take into their calculations at all, namely, the weather! It is the immemorial boast of that State that it possesses climate instead of weather; and, indeed, it would be difficult to name a region of such varied attractions through which an excursion of weeks could be arranged without fear of disaster at any point through interruption by storms. Such had been the

record of the Institute excursion-party in Montana, Washington, Oregon and California. The schedule of the journey had been absolutely free from any interference due to storms; and nobody dreamed of such an interference in Southern California. But on October 13th it regularly and vulgarly rained all day, just as it might have done, over and over again, in the less fortunate East. Undoubtedly, this rain was much needed by everybody except the members of this particular party. It was needed on general principles by a State suffering under two years of exceptional drought—though, to meet this necessity, Providence (in the opinion of the Institute party) might just as well have waited one more day before sending it. And it was needed also, on special grounds, to extinguish the destructive forest-fires which were devastating the Sierra and the Coast Range at several points.* In this respect, no one could have dared to suggest to Providence a day's delay. There is too much at stake, when a forest is on fire, to leave room for consideration of the convenience of tourists!

It was, therefore, with due humility that the Institute party received this single intrusion of weather upon climate. Yet it could not be blamed for keenly regretting the result, which was, that the special train sped in blinding rain and mist through Cresta Blanca, Riverside and Redlands, while its occupants could gain only, as they flattened wistful noses on the window-panes, dim glimpses of the glories into which they might not enter.

The Copper Queen Mine.

On Saturday afternoon the "Institute Special," after a brief stop at Tucson, Arizona, and a trip from Benson over the Arizona and Southeastern railroad, arrived at Bisbee, the locality of the famous Copper Queen mine. Mr. James Douglas, the President of the Institute, being also the President of the Copper Queen Mining Co., it was naturally expected that special efforts would be made at this place to extend to the party a reception worthy of the occasion. But the reality far exceeded any anticipations that had been conceived regarding it. Notwithstanding the fact that, by reason of unavoidable, though

* It was only a day or two after the ascent of Mt. Tamalpais by members of the Institute that fire destroyed a large part of the beautiful redwood forest through which they had passed on their way.

unexpected, rai[illegible]. Bisbee was reached much later in the day than had been planned, the reception and entertainment given to the party commanded general surprise, as well as delight. The first feature was a luncheon served in one of the great stopes of the Copper Queen mine, at which the guests arrived by first descending 400 feet in cages through the shaft, and then walking nearly half a mile through galleries illuminated with countless candles, reinforcing the electric lights. In the stope, tables had been set; and the luncheon was served, with miners as attendants, from tin dishes, cups and coffee-pots, such as the miners use—only brand-new for the occasion. The ordinary ladders had been replaced with convenient staircases, so that, after the luncheon, even the ladies could easily climb to higher levels, and inspect "in place" the ore of the mine. The visitors were also conducted to a stope in which mining-work was actually going on. President Douglas's paper on the Copper Queen mine, presented at the meeting in San Francisco, was available to every visitor as a guide to further inquiry; and as many as desired to make additional investigation were provided with competent guides for the purpose. It seems appropriate to remark, here, that this is the true solution of the question, how to treat a large and miscellaneous company of visitors at a mine—namely, by furnishing to those specially interested the opportunity to study what they desire to see, without dragging the whole party through places which do not interest them.

Those who did not stay in the mine were entertained with a trip to the Mexican boundary, at Naco, 12 miles away, where they could step across the line, buy little souvenirs in the way of lace, etc., and acquire the ability to remark with truth, thereafter, that they "had been in Mexico."

In the evening, a banquet given at the Masonic hall of Bisbee constituted the crowning surprise of the occasion, furnishing, at the close of the long series of entertainments given to the Institute party, a *finale* worthy of the similar entertainment at Keswick, Cal., with which the Californian part of that series had begun. Here, as there, the miners themselves had essentially co-operated in the work. The local committee, headed by Mr. Ben Williams, Superintendent of the Copper Queen mine, and the ladies of Bisbee, headed by Mrs. Lewis Williams, wife of

the Metallurgical Superintendent, utilized the forces of both mine and town to adorn this feast; and it is safe to say that, without their aid, the liberal hospitality of the Copper Queen Co. could not have achieved the brilliant success which characterized this banquet. An excellent local band played in the public square outside the building; in the hall itself an admirable stringed orchestra (likewise provided by home talent) discoursed sweet music during the evening; the room had been transformed by the deft hands of the ladies, and by means of flags and foliage, into a bower of beauty; the *menu* was worthy of Delmonico; and the attendance, executed by foremen and employees of the mine, was more than "professional" in efficiency and style.*

A noteworthy feature of the occasion was the center-piece, placed in the hollow square which was formed by the tables, namely, a large block of ice, in which a bouquet of natural flowers was enclosed, undiminished in apparent freshness and beauty.

President Douglas presided at the banquet, and appropriate speeches were made by representatives both of the Copper Queen Co. and of the Institute.

At a late hour the guests returned to their special train, and proceeded on their homeward way.

Across Arizona.

Saturday night and Sunday, Oct. 16th, were spent in crossing the Territory of Arizona northward, with many delays, due to accidents and difficulties of transportation, which call for no comment here. At Phœnix, the present capital of the Territory, and at Prescott, the former capital, the party was met by local committees, and entertained with such attentions (in the way of drives, etc.) as its brief stay permitted. On Monday afternoon, Oct. 17th, it arrived, *via* Ash Fork from Prescott, at Flagstaff, Arizona, where it was found impracticable, by rea-

* This feature received, as it deserved, the recognition of special thanks from the guests. The one deficiency usually experienced in such cases is that of skilled waiters for the table. Material supplies can be easily secured by telegraph and railroad. Efficient table-service is not so easily improvised. In the present instance, the officials and employees who masqueraded as waiters evidently took pride in doing this work with professional thoroughness, and must have qualified themselves for the performance by no little previous drill.

son of a recent storm and the lateness of the season, to convey the entire company by stage to the Grand Cañon of the Colorado, some 70 miles distant, and a portion of the party, filling one of the Wagner sleepers, therefore decided to proceed eastward, leaving the rest either to go to the Grand Cañon or to wait, with the remainder of the train, at Flagstaff, until the return of those who should make that trip.

Before this division of the party, however, the famous astronomical observatory at Flagstaff was visited, and on Tuesday, Oct. 18th, an excursion was made to Walnut Cañon, near Flagstaff, one of the most picturesque and extensive localities of the "cliff-dwellings" to be seen in this country. On Wednesday the Grand Cañon party and the homeward-bound party left Flagstaff. The small number who remained made an interesting trip on Thursday, Oct. 20th, to the cave-dwellings, situated a few miles from Flagstaff, at the summit of a lava-crowned hill. These are not to be confounded with the cliff-dwellings of Walnut Cañon and other localities, though they may be of approximately the same age. They are caves, constructed or enlarged in the volcanic rock, connected by underground passages and fortified with rough walls against attack. Their position commands a magnificent wide view of the table-land occupied by the Coconino forest and its included parks.

Concerning the Grand Cañon of the Colorado river in Arizona, nothing will be said in this report of the excursions connected with the California meeting. The unique sublimity and beauty of that scene have been described (notably in Dutton's monograph on the Tertiary History of the Grand Cañon, Chapter VIII., p. 140 of Monograph II. of the U. S. Geological Survey, and in the publications of Major Powell) as thoroughly as the resources of language would permit; and no one who has read these accounts will be inclined to attempt another, though neither these nor any others could adequately represent the Grand Cañon to those who have not looked upon it. It is sufficient for the purpose of this record to remark that the Institute party returned from its trip on Saturday, Oct. 21st, after an unexpectedly comfortable experience, and practically speechless with regard to what it had seen.

The same night the special train left Flagstaff for the East,

and proceeded by way of Albuquerque and Kansas City* to Chicago, where the excursion formally ended, on October 24th.

In closing this meager sketch of a memorable journey, the Secretary deems it both a duty and a pleasure to acknowledge the services of Mr. Theodore Dwight, Assistant Treasurer of the Institute, who (under the general direction of President Douglas) organized the excursion from the East, directing all its details, and controlling all expenditures made for the party. Some notion of the efficiency of his services may be gathered from the statement that the total amount collected from each member of the party for the trip, beginning and ending at Chicago, covering nearly 10,000 miles of railway-travel, with meals and sleeping-accommodation, and including the side-trips to the Yosemite and the Grand Cañon, was $265; and that, of this amount, after final settlement of all accounts, a dividend of $29.16 was returned to each member of the party. But no mere financial statement can fully express the amount of vigilance, patience and executive ability involved in this work.

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* From Kansas City, the following telegram was sent to the convention of the California Miners' Association, assembled on that day in San Francisco:

"KANSAS CITY, Oct. 23, 1899.

"*E. H. Benjamin, Secretary, San Francisco, Cal.*

"With fresh and grateful memories of the Golden State, the members of the American Institute of Mining Engineers, returning from their memorable trans-continental journey, send greeting to the California Miners' Association, from which they have received such magnificent hospitality.

"R. W. RAYMOND, *Secretary.*"

PAPERS.

The Platinum Deposits of the Tura River-System, Ural Mountains, Russia.

BY C. W. PURINGTON, BOSTON, MASS.

(New York Meeting, February, 1899.)

It is from that portion of the northern Ural included in the Goroblagodat and Bisersk mining districts, in the Perm Government, which is drained by the Tura river, and more especially by its branches, the Iss and Veeya rivers, that the largest portion of the yearly platinum-product of Russia now comes. It follows that this small area, of less than 2000 square miles, may be called the principal platinum-producing district of the world.

The Iss river, the bed and banks of which have been found to contain the richest platiniferous sands, takes its rise on the east slope of the main Ural divide, in latitude 58° 50′ N., and flows in a tortuous, but generally easterly, direction for 30 miles to its junction with the Tura. The Veeya river rises at a point 10 miles south of the source of the Iss, and flows east, approximately parallel to the Iss, also into the Tura. As the valley of the Tura itself is platiniferous only by virtue of the detritus which it receives from the Iss and the Veeya, its course above the junction of these two tributaries need not be described. Below the confluence of the Iss with it, the Tura flows northeast 60 miles to the town of Verkotoor, below which important settlement the river has not been found platiniferous to a workable extent. From Verkotoor the Tura flows southeast 200 miles, until, just below the city of Tumen, it joins the Tobol, which flows north into the Irtish river. This, in turn, is a tributary of the Ob, the great river which empties north into the gulf of Ob, an arm of the Arctic Ocean. The Ural divide, forming the watershed between the tributaries of the Ob on the east and the Volga on the west, although the dividing-line between Asia and Europe, is not the boundary between Russia and Siberia, the latter being 150 miles east of the source

of the Iss. The nearest railway point to the district under consideration is Kooshva, a station on the Perm-Ekaterinenburg Railroad, 35 miles south of the junction of the Iss and Tura rivers. From Kooshva the journey must be made by post-carriages.

Platinum was not discovered in the Goroblagodat area until 1825, six years after it was found in the Ural, the first discovery having been in the lands of Verkisetsk, one of the more southerly districts. Nor did the Iss district attain the first rank in production until after 1879, some ten years after the commencement of the systematic publication of the results of exploitation. Previous to this time the larger share of the product came from the district of Nizhni-Tagil,* about 130 miles south of the Goroblagodat district. The product of platinum from the entire Ural has never in a single year greatly exceeded $2,000,000 in value, the largest product by weight having been, in 1893, something under 6 tons. The value of the metal per ounce has increased, with some minor fluctuations, from $1.58 in 1869 to $10.18 in 1897. These figures are reduced from the Russian equivalents, the rouble being taken at 52 cents. According to the Russian method of reckoning, the increase has been from 1600 roubles a pood in 1869 to 10,300 roubles a pood in 1897.†

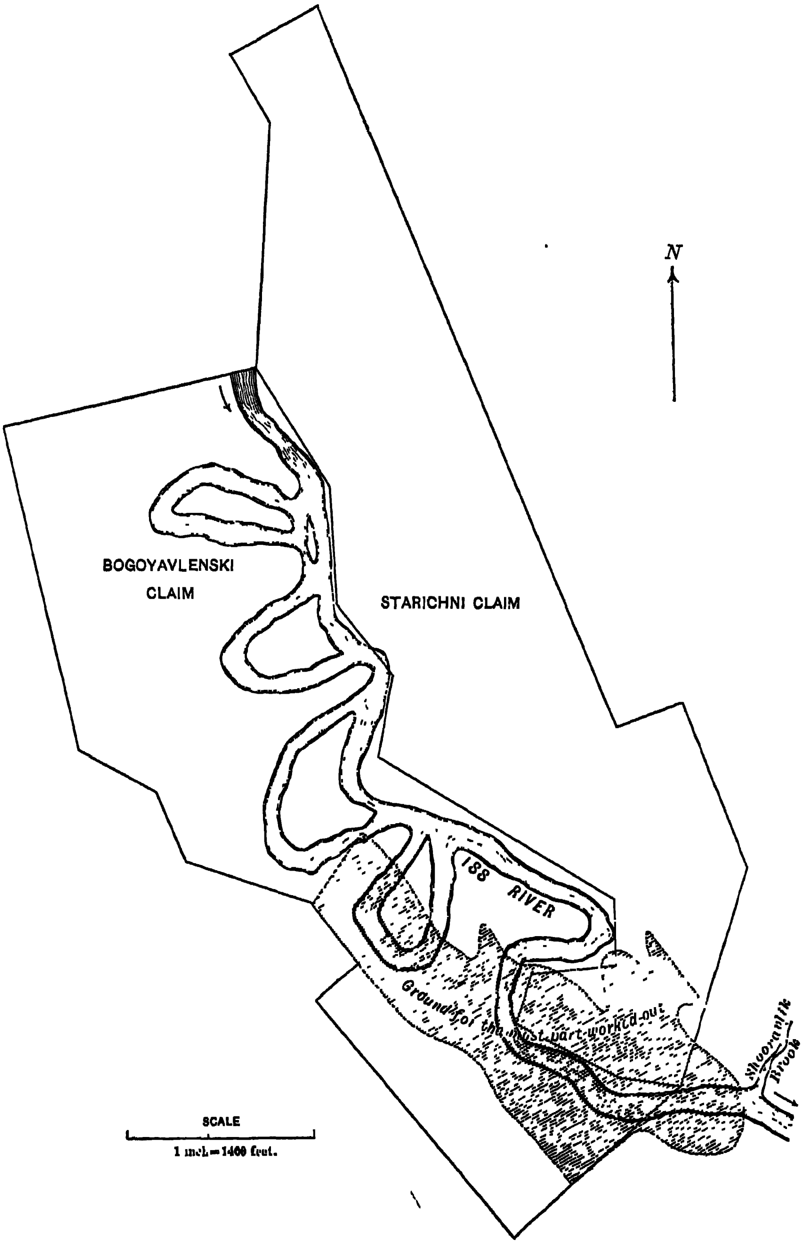
The topography of the Goroblagodat district presents no striking features as regards elevation. Like the northern Ural in general, the region is one of old mountains, worn down nearly to base-level, flood-plain streams that do little cutting, and silted river-valleys. The Tura presents great numbers of ox-bow curves, cut-offs, and crescent-shaped lagoons, such as occur in the Mississippi. Their dimensions are frequently large, and indicate that the volume of water was formerly much greater than at present. The river itself, in the platiniferous area, does not now exceed 300 feet in width. The same topographic features are exhibited on a smaller scale by its two tributaries, the Iss and the Veeya. As the accompanying plan, Fig. 1, taken from Prof. A. Saytzeff's recent monograph,‡ will

* Mr. G. F. Kunz has published in the *Report on Mineral Industries*, Eleventh Census of the U. S., 1892, p. 341, information and data concerning the Demidoff platinum-workings at Nizhni-Tagil.

† *Die Platinlagerstätten am Ural*, A. Saytzeff, Tomsk, 1898.

‡ *Op. cit.*

Fig. 1.



Plan of a Portion of the River Iss.

illustrate, there are sections of the Iss where the river appears to have lost itself in a silted valley, at such points more than 1200

feet in width. The streams of this system, as well as numerous other streams of the Ural which I have seen, show all the characteristic operations of flood-plain rivers in general—among them, that of acquiring a constantly increasing swing by always cutting into the concave bank and depositing accretions on the convex side.

Mr. J. E. Spurr* has recently published some valuable observations with regard to the location of gold-deposits along the Yukon river and its tributaries, where conditions are presented similar to those here described. As Mr. Spurr shows, the point in an ox-bow curve of a river at which heavy metals held in suspension are most likely to be deposited is that just at the up-stream end of the curve, on the convex side. In the case of the Tura-system it is evident that this is true, not only of those curves which are now being formed, but also of the larger ancient channels, the existence of which appears to have been, to a considerable extent, overlooked hitherto.

As has been said, the entire region is one of great denudation; and, as there has been no removal or transportation of residual material by glaciation, the rocks are everywhere covered with layers of sub-angular fragments, nearly or quite in place, capped by thick layers of loam and matted vegetation, commonly known in the country as "turf." Consequently, it is only where the streams have cut slightly through this superficial layer, and the bed of gravel that lies underneath it, that natural exposures of the rock in place can be seen. So thoroughly, however, has the Goroblagodat district been prospected for platinum-bearing beds, that it has been possible to map with considerable accuracy the rocks occurring in the district. This has been done recently by Prof. Saytzeff, who has embodied the results of his work in the excellent monograph already cited. A passing reference to rock-occurrences will be sufficient for the purpose of this paper.

Peridotites, olivine-gabbros and the serpentinous decomposition-products of these rocks compose the three areas in the western portion of the field, the centers of which are the small hills, Kachkannar, Saranaya and Veresovy respectively. The remarkable feature of these rocks is their extremely basic char-

* "Geology of the Yukon Gold District, Alaska." *Eighteenth Annual Report, U. S. Geol. Survey*, 1896–7, Part III., p. 360.

acter. Augite, hornblende and olivine are their characteristic minerals, the lime-feldspars occurring in very small quantity. As accessory minerals, magnetite and chromic iron are present in large amount, besides—what is of remarkable interest—particles of native platinum.

The first systematic search for platinum as an original constituent of the rocks of the Ural appears to have been conducted by A. Inostranzeff* on basic olivine rocks from the Nizhni-Tagil platinum-field. His investigations were made in 1892. Previous to this time, according to Messrs. Bourdakoff and Hendrikoff,† platinum had been found by both Daubrée and Engelhardt as an original occurrence in basic rocks; but no record is given of the dates, and I have been unable to find published notices of the investigations.

M. Inostranzeff says that the principal component of the rock examined by him is olivine, and that the serpentine which it contains probably represents the decomposition of other basic elements. Dolomite in scattered grains is also present, and there are numerous grains of chromic iron. The rock contains many nodules or "blebs," even more basic in character. "In very rare pieces of the included rock it was possible to show, by the aid of a strong glass, the presence of native platinum, partly in grains, partly in leaves, in the chromic iron."‡

Saytzeff's investigation appears to have been the first attempt to find the source of the platinum in the Goroblagodat district. He says that, according to his results, platinum occurs in an original condition in the peridotites and the other olivine rocks of the region described, and also in the porphyrite, gabbro-diorite and syenite-gneiss. The peridotite, however, contains by far the larger part of the platinum. Tests were made by both chemical and mechanical methods.§

In July, 1898, I broke up and panned several pieces of the

* A. Inostranzeff, *Gisement primaire de platine dans l' Oural.* Communicated Nov. 7, 1892, to the Mineralogical Section of the Society of Naturalists of St. Petersburg.

† N. J. Bourdakoff and I. M. Hendrikoff, *Déscription de l'exploitation de platine de J. I. Bourdakoff et fils, et de la compagnie V. J. Bourdakoff et V. N. Charavieff, sises dans l'arrondissement minier de Goroblagodat (Koushva), Monts Ourals, avec un court aperçu historique de l'industrie du platine en Russie. Traduit du Russe par G. O. Clerc.* Ekathérinebourg, 1896.

‡ Inostranzeff, *op. cit.*

§ Saytzeff, *op. cit.*

peridotite which I had obtained from the bed of the river Iss, a mile above its junction with the Tura. The test showed many fine colors of platinum; the quantity obtained from 20 pounds of rock not exceeding two cents in value. Inostranzeff gives as the results of two assays of the ferrous "blebs" in the rock of Nizhni-Tagil, a figure corresponding to $50 per ton. It cannot be said, however, that any systematic testing of the platinum-bearing rocks has yet been done. Considering the large masses of peridotite exposed, this question seems worthy of further investigation.

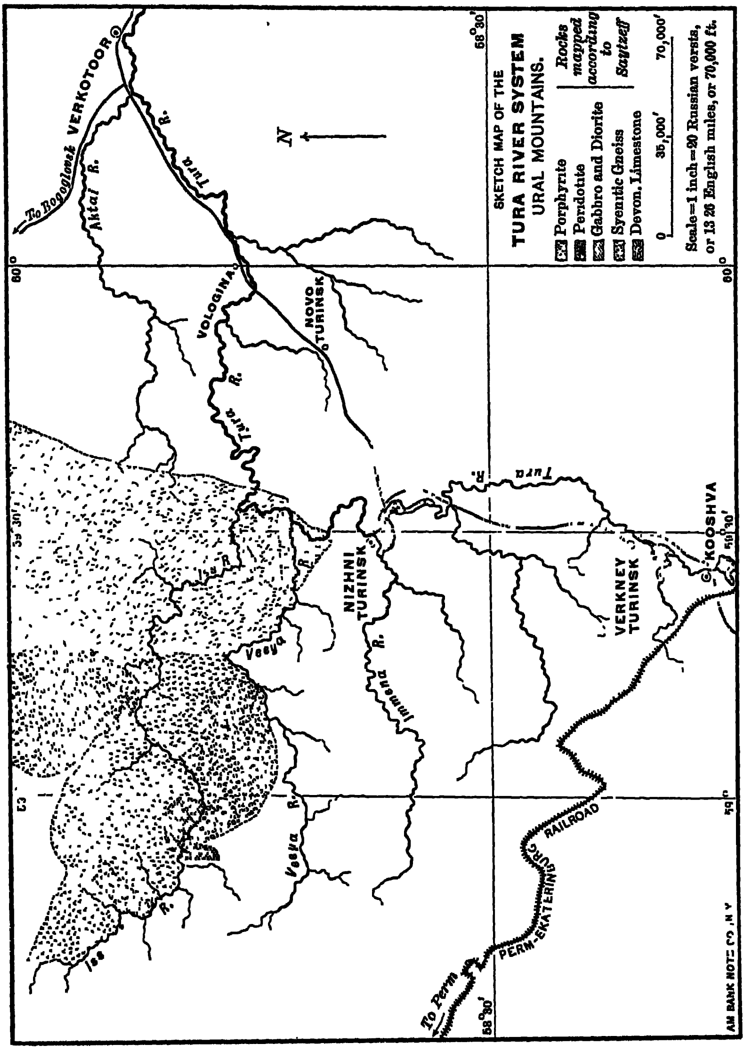
The distribution of the remaining igneous rocks and of the limestone may be seen from the accompanying map, Fig. 2. The limestone, which alone requires further mention as bearing on the occurrence of platinum, forms two geological islands in the midst of the large diorite area in the central portion of the field. Its age is Lower Devonian. The beds strike N. 20° W., dipping only 15° to the N.E. The rock makes bold cliffs along the banks of the Iss, but in the river-bed the limestone formation presents a corrugated surface, due to the alternation of more and less soluble layers, which permits the development of natural riffles for catching the platinum and gold. It is said in the district that the richest gravels are those which lie directly on the limestone-beds, although the limestone itself, so far as is known, contains not a trace of platinum. The limestone is, however, remarkable as containing veins and nodules of cinnabar, mixed with a gangue of calcite, which, in the process of erosion, are broken from the matrix, rolled about in the stream, and washed out of the placers together with the platinum and gold.

This occurrence of cinnabar in the limestone of the Iss was noted by Erman as far back as 1833*, but, so far as I am aware, the deposit has never been sampled with the purpose of determining its economic value. It is clearly a replacement deposit, there being no sharply-defined form to the ore-bodies, and no definite, sharply-cut walls to the veins. The gangue is entirely crystalline calcite, largely stained red by the cinnabar. As the limestone contains also dikes of volcanic rock, it seems a plausible hypothesis that the deposition of quicksilver-ore in this

* Erman, *Reise um die Erde*, 1833, i., p. 368.

limestone is a final phase of the volcanic phenomena which are responsible for the presence of the igneous rocks of the district. Although the depositing heated waters have doubtless taken advantage to some extent of previously-existing open

FIG. 2.



fissures in the limestone, it appears that, for the most part, they must have made their way through the mass by chemical action.

The platiniferous gravels worked along the Tura river-system are practically limited in lateral extent by boundaries parallel

to the Iss, Veeya and Tura rivers and their tributaries, and lying from 200 to 800 feet away from these streams on either side. In the larger reaches of the Tura the entire width of the platinum-ground attains more than half a mile. In length the workable ground may be said to extend from the sources of the Iss and Veeya to the town of Verkotoor, above named. To give the depth of this deposit in reasonable and at the same time comprehensible terms is a rather difficult task, by reason of the Russian custom of making a sharp, and often an apparently unwarranted, distinction between the "turf," or upper portion of the gravel, and the pay-gravel beneath. It is true that the word "turf" is frequently applied to designate the mass of matted and decayed vegetation to which it properly refers; but more often it signifies, in the miner's sense, the portion of the gravel which is too poor to wash, and which is stripped off before the pay-gravel beneath can be worked. Thus in giving the thickness of placer-deposits, not only here but in Russia and Siberia generally, one must bear in mind the fact that other methods of working the deposits may exist besides those which the Russians employ. If one considers the deposits with the idea in view of their being worked as a whole, "turf" and gravel together, the entire thickness of the loose material overlying the bed-rock must be given as the thickness of the platiniferous bed, and the values now estimated by the operators must be correspondingly corrected.

Thus, the thickness of the platiniferous bed, as generally considered, does not exceed 4 feet, while the turf which overlies it, and has to be stripped off, has a thickness varying from 5 to 20 feet. In the present paper, however, the ground is considered from the standpoint of one who proposes to work the material as a whole. In this sense the gravel may be said to vary from 8 to 24 feet in thickness along the Iss and Veeya rivers; and although its thickness along the Tura has not been determined, the depth undoubtedly increases greatly in the lower reaches of the streams.

The pebbles of the streams are exclusively fragments of the rocks which occur in place within the limits of the Tura river-basin. They are rarely well-rounded, for the most part sub-angular, and at times almost unworn. In certain stretches of the river, boulders of large size are not infrequent, while other

portions appear to be free from those above 18 inches in diameter. In the Iss, 25 per cent. of the rock is too large to be taken to the washing-machines, and must be sorted out. There is no evidence here, or in other gold- or platinum-placers of the Ural, that there has been any transportation of material by glacial agencies. Sand and clay are the cementing materials, the clay being regarded here, as elsewhere in the northern Ural, as an especially favorable indication of values. Near the surface, in the parts of the river-valleys not actually occupied by the rivers at present, the bed consists of black peaty material, matted together with the roots of weeds, which extend downwards to the depth of 4 feet.

The platinum and gold occur, in the material which has been worked by the present operators in the field, in a ratio of five parts to one. As I have taken special care to determine by panning, these precious metals occur also in the overlying material throughout the area. At a distance of 80 miles below the area of peridotite in which the platinum for the most part originates, one may pan colors of it at the very grass-roots and over any portion of the area of the silted valley, which is there 2000 feet in width. The platinum from the Iss is known as the purest which comes from the Ural. That of the Veeya is more largely combined with the rare accessory metals, and that from the Nizhni-Tagil district is still more impure.

The metal, as found in the placers, consists of platinum, combined to a greater or less extent with the rarer metals, notably osmium and iridium. R. Helmhacker has described the combinations in which the impure platinum occurs, and the methods of treating and refining it.* In physical form neither the platinum nor the accompanying gold presents peculiarities. The scales and granules in which these minerals occur in the rivers cannot be said to be "coarse," but even in the upper reaches where the platinum is rough, and shows evidence of little wearing, the colors, though not scaly, are rather finely divided. It is worthy of notice that the platinum loses less in transportation by the currents than the gold. Thus when one compares the gold- and platinum-particles taken from

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* R. Helmhacker, "The Occurrence of Platinum in the Ural Mountains," *San Francisco Mining and Scientific Press*, p. 280, September 17, 1898.

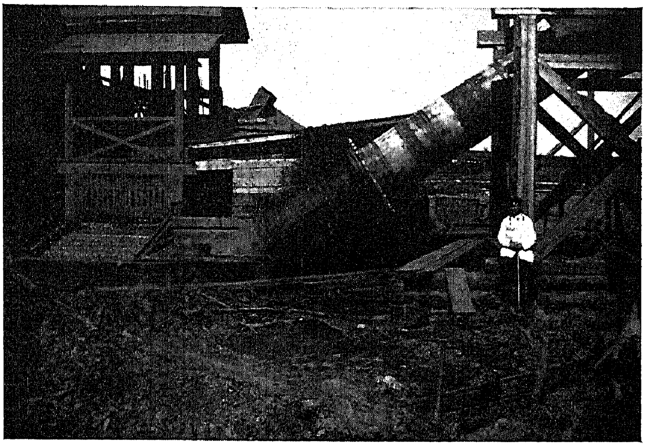
the stream at the junction of the Iss and Tura with those taken out 50 miles farther down the Tura, one finds that, while the size of the platinum-particles in both places is practically the same, the gold seems to have suffered a finer division in its journey to the lower locality.

The value of the whole deposit in the precious metals, reckoned from the grass-roots down, will not exceed 40 cents to the cubic yard. Nor will the average in any special locality be greatly below this figure. It is estimated that the higher reaches of the rivers, especially of the Iss, where the most work has been done, have yielded better than this. For example, I have compiled from the data given me in the field with regard to the amount of rich and turf-material turned over during the last twenty years by the various miners operating on the Iss, the value per cubic yard of the whole material. This result gives for the upper portion of the Iss 63 cents per cubic yard and for the lower portion 65 cents, the gravel averaging 3½ yards in thickness. On the other hand, the yield of the larger valley of the Tura, at present only exploited by peasants for the most part, working with primitive dredging-machines which I shall describe, is much less easy to estimate. It appears, however, according to figures given by peasants who operate on the tribute-system, that the top-gravel, lying in the river-bed itself, under 7 feet of water, carries platinum, mixed with some gold, to the value of 52 cents to the cubic yard. As it is, however, necessary to allow for poor patches in figuring up this immense area as a whole, I have preferred to err on the side of low, rather than of high values.

The season for working the gravels in this region is limited to five months in the year, from May 1st to October 1st, although stripping of the turf is carried on during April and October. The ordinary Russian methods of washing auriferous and platiniferous sands are too familiar to need description in detail. The machine shown in Fig. 3, in use at one of the gold-placers near Kooshva, is quite typical of its kind, and will serve for an illustration of the methods in use.

As may be seen in the illustration, it is constructed almost entirely of wood, which is an advantage in this well-timbered region, remote from mining-machinery plants. The gravel, brought from the beds of sand which have been stripped by

FIG. 3.



Type of Washing-Machine Used in the Ural.

FIG. 4.

Peasants' Dredge-Boat on the Tura River.

open-cutting, or from the shallow tunnels run under the turf, is hauled in carts up an inclined platform to the top of the upright cylindrical tank. This is often 7 feet in depth and 8 feet in diameter. It is floored with a circular-punched iron plate or grizzly, with ¾-inch holes. To a central vertical revolving shaft are fastened horizontally four 12-inch timbers 5 feet above the floor. These form a rectangular frame having eight projecting arms. To these arms are bound a number of vertical iron bars to serve as puddling-irons, and their lower ends, with a face 1½-inch square, come within ⅛-inch of the iron floor. When the central shaft is revolved, the iron bars, moving in a circular path, constantly stir and disintegrate the clayey mass fed into the machine from the top. The water, raised by a small centrifugal pump, is fed from a circular pipe, running around the inside of the tank near the top. The whole plant is operated by a steam-engine of 25 or 30 horse-power. The machines of this type usually have a capacity of about 500 cubic yards per twenty-four hours. The gravel bearing the values passes through the holes in the grizzly directly onto the sluice-boards, a frame having a 4.5 per cent. grade, and presenting a flat surface 6 by 30 feet in dimensions. The frame is covered with coarse matting, held in place by lateral cleats which serve the purpose of coarse riffles. The first 10 feet of the frame is usually enclosed behind a locked gate, and it is claimed that over 85 per cent. of the values is saved in the first 4 feet of the box. The clean-up is made at least once, and usually twice, every day. Usually no attempt is made to give the material a second washing at once, although now, in many parts of the field, the tailings of former years are being rewashed. The tailings are elevated in the more improved form of machines, as shown in Fig. 3, by a form of Archimedes' screw, to a platform, from which they are hauled in carts and dumped over the end of the bank. It is reported that the cost of hauling and washing the gravel by this method is not above 15 cents per cubic yard.

The principal variation from this type of machine is the one in use for gravel in which little clay is mixed. This differs in having, instead of the vertical cylinder with its revolving puddlers, a long, slightly inclined horizontally-revolving cylinder, or truncated cone, made entirely of punched iron, and open at both ends. This simple form of separator is very

efficient, and works more rapidly than the type first described. It seems to be more in favor in eastern and western Siberia than in the Ural. Although these Russian machines are efficient in saving most of the platinum, and are always said to save above 90 per cent., I am of the opinion, formed both from observation and from panning of the tailings in various places, that their efficiency in saving the more finely-divided particles is open to question. An advantage which may be urged for the machines of the type described, beside that of their being constructed of wood to such an extent, is their cheapness of construction. The machine alone, of the capacity of 500 cubic yards per day, costs less than $1000, including erection.

It will be seen, however, that such apparatus is of no service where the amount of water to be dealt with is large, or where the gravel cannot readily be shoveled by hand from the bank into carts, and hauled thence to the platform of the machine. Moreover, in areas like the lower Tura valley, where the gravels lie for the most part below the level of the river, it is impossible to test the ground by the ordinary Russian method of digging large shafts. Thus it cannot be determined, in this portion of the field, where the most promising spots are located; and, in case these were found, no method is in general use by which the valuable metals in the sands could be extracted. It has been apparently left to the peasants, who work in the lower reaches of the river on leases, to devise a system of working the wet ground which, so far as it goes, is very successful. Fig. 4 shows one of the dredging-boats used by the peasants at the village of Vologina, at the point where the post-road from Koongoor to Verkotoor crosses the Tura.

The boat or raft, 30 feet long, is made simply of a few logs lashed together. A slit or opening 15 inches wide, in the middle of the boat, extends the entire length of it. A large iron shovel, with a scoop-blade 2 feet long and 1.5-foot wide and a handle 12 feet in length, is free to play back and forth in this slit. It is prevented from falling through by a cross-piece which is tied near the top of the handle, its end projecting over the two sides of the opening, along which it freely slides. Near one end of the raft is a windlass from which depends a chain, which latter is made fast to either edge of the shovel-blade, and by which the shovel is hoisted when full of gravel. Still farther

toward this end of the raft is an ordinary peasants' type of washing-machine, consisting of a small flat-lying punched iron plate, over which the gravel is rabbled by hand, and a short sluice-box with six lateral riffles; also a hand-pump for water. The method of operating is extremely simple. The raft is anchored in a favorable position, and the shovel is pushed by hand as far into the bed of the river as possible. Then it is raised by means of the windlass; its contents, amounting to 80 pounds of gravel each time, are dumped upon the washer; and the clean-up is made after 100 shovelfuls. It would not here be in place to enter upon the details of the operation and its results, but it is sufficient to state that the more than ordinarily energetic peasant who owns one of these boats pays a tribute on both platinum and gold which is by no means small, and hires a crew of eight laborers (four men and four women) for the day's work of ten hours. He then realizes a profit of $1.10 a day, which, according to the scale of living in that portion of Asia, is equal in value to four times its amount in the United States. There were, at the time of my visit, some fifty or sixty of these boats in operation on the Tura within a stretch of 10 miles.

The water in the Tura where these boats are working is 7 feet deep, and the river is something over 300 feet wide. Many old channels exist in it here, as in its tributaries higher up; and the entire width of its flood-plain valley varies from 1500 to 2000 feet. Pannings of platinum may be had at the surface in all parts of the valley, and it seems likely that there exists a large area of platiniferous ground, up to the present unworked. The depth to which the gravel extends, however, in this lower portion of the river is not determined, and must, for the present at least, remain an unknown factor.

The Occurrence, Origin and Chemical Composition of Chromite; With Especial Reference to the North Carolina Deposits.

BY J. H. PRATT, CHAPEL HILL, N. C.

(New York Meeting, February, 1899.)

INTRODUCTION.

IN a recent paper* on the origin of corundum associated with the peridotites of North Carolina, attention was called to the constant occurrence of the mineral, chromite, in these rocks. The field-data obtained during the preparation of that paper have been used largely in the present paper. During the past summer the general occurrences of chromite have been carefully studied, and those in North Carolina have been especially examined in the field.

It is purposed to give, in this paper, the reasons why the chromite should be regarded as having been formed at the same time with the peridotites, having been held in solution by the molten mass of the peridotite, and crystallizing out among the first minerals as the mass began to cool.

This theory is essentially the same as that advanced by me for the origin of the corundum associated with the peridotite rocks,† and a similar line of reasoning has been used to substantiate the theory proposed.

Investigations concerning the igneous origin of some of the ores have been materially aided, during recent years, by the skillful experiments of Morozewicz‡ and Lagorio,§ and by researches that show us, more clearly, why we should regard a fused mass of rock as a liquid, having similar properties to an ordinary solution. These experiments have shown that a molten basic glass, similar in composition to the basic magnesian rocks, dissolves alumina readily, and that upon cooling, the first minerals to separate out are corundum and spinel.

* *Am. J. Sci.*, 4th series, vol. vi., July, 1898, p. 49. † *Ibid.*, p. 50.
‡ *Zeitsch. für Kryst.*, vol. xxiv., p. 281, 1895. § *Ibid.*, p. 285.

Lagorio, in discussing the solubility of alumina in a molten glass, points out the distinction between the fusibility of compounds and their solubility in that menstruum.

A fused mass of rock is capable of holding different minerals in solution; and, as this mass begins to cool, these minerals will separate out, not according to their fusibility, but according to their solubility in the fused mass. The more basic minerals, being the less soluble, would be the first to separate out; and this crystallizing or solidifying out from the molten mass would take place first on its outer boundaries, for here it would cool first. Convection-currents would tend to bring new supplies of material to the outer zone, where crystallization would take place. This is not the same as the differentiation of rock-magmas, but is essentially the idea advanced by Becker* in a paper "On the Fractional Crystallization of Rocks," at the close of which he says:

"The simple principle of fractional crystallization, which is the very opposite of magmatic differentiation, is in most respects thoroughly well understood. It is known to be practicable by hundreds of thousands of experiments, many of them on a fairly large scale, and its action is so rapid as to bring about in days diversities of composition which it would take centuries to bring about by processes depending on molecular flow. In dikes and laccolites of mobile lavas fractional crystallization seems inevitable, while the convection attending it is inconsistent with segregation by molecular flow."

The study of the origin of ore-deposits has been, for the most part, confined to the sulphides, or what are commonly classified as the metallic ores—the more recent treatises on this subject being those of Vogt,† Adams‡ (partly a *résumé* of Vogt's paper) and Posepny,§ with the discussions brought out by the latter's paper.

Many of the ore-deposits have been recognized as having some connection with igneous rocks, but it is only in comparatively recent years that some of these deposits have been shown to be unquestionably of igneous origin. Prof. Vogt, in his papers, points out two classes of ore-deposits that are intimately related to igneous rocks: the titanic iron-ores, and the

* *Am. J. Sci.*, 4th series, vol. iv., 1897, p. 261.

† *Zeitsch. für Prak. Geol.*, Nos. 1, 4 and 7, 1893.

‡ "On the Igneous Origin of Certain Ore-Deposits." Read before the General Mining Association of the Province of Quebec, Montreal, January 12, 1894.

§ "The Genesis of Ore-Deposits," *Trans.*, xxiii., 197.

sulphide-ores containing nickel. The latter are described as occurring in norite, and sometimes so related to it that a gradual passage is observed from the normal norite through a pyrrhotite-norite to the pure ore, while at other times there is a sharp contact between the ore and the norite. The masses of ore are found in the majority of cases near the contact of the norite with the gneiss. Vogt regards these "as strictly comparable to the basic borders or edges so often observed about granites and other igneous rocks, in which the basic portions are sometimes marked by similar gradual passages, and in some cases by gradual transitions."

Adams,* in commenting on the sharp contact of the pyrrhotite with the norites, says:

> "These sharp transitions are easily explicable when one considers that any part of the magma having once separated itself from the rest, being possessed of a decidedly different specific gravity, and perhaps of a different degree of fluidity, would, if the whole mass were caused to move, keep itself separated by a comparatively sharp line from the rest of the molten mass."

As the deposits of corundum and chromite in the peridotite rocks are similar in their occurrence and formation to these sulphide-deposits just referred to, it seems advisable at this point to describe briefly the general occurrence and character of these rocks.

Occurrence of Peridotites, etc., in the Eastern United States.

Extending from Tallapoosa county, in eastern central Alabama, to Trenton, N. J., there is a narrow belt with disconnected outcrops of these rocks. North of New Jersey (in New York, Connecticut, Massachusetts, New Hampshire and Maine) the outcrops are fewer, and do not make such a continuous belt as those to the south. Where there is a considerable outcropping of these rocks, it is characterized by the stunted growth of the few trees and by the small amount of coarse grass able to draw sufficient sustenance from the impoverished soil, and it presents a very barren appearance. The hillside is usually thickly scattered with loose boulders and fragments of the altered peridotite.

* *Op. cit.*, p. 19.

In North Carolina and in the more southern portions of this belt the prevailing type of rock is dunite, while in the northern portion the secondary rocks, serpentine and talc, are prominent.

Throughout nearly the entire southern portion of the belt, the peridotite rocks show a freshness almost to the very surface of the exposure, and there are but few localities where there is any considerable area of peridotite entirely altered to serpentine. Thin sections of the dunite show, under the microscope, an alteration to serpentine between the particles of dunite. These rocks have been shown to be of igneous origin,* and the principal reasons why they should be so regarded are given here.

The blunt lenticular form in which we find these peridotites would be difficult to associate with any origin but that of an intruded igneous mass, which would also account for the apophyses that have been observed shooting off into the enclosing gneiss.

At Webster, Jackson county, N. C., a large block of gneiss is completely enclosed by the peridotites in such a manner as could only be attributed to the intrusion of the latter in a molten condition.

The line of separation of the peridotites and the gneisses is always sharp, and there is no transitional zone from the acid gneiss to the basic peridotite. Under the microscope the latter rock shows the granular structure characteristic of plutonic origin, the grains fitting perfectly into each other without cementing-material.

Associated with all these peridotites is the mineral chromite, which occurs in imbedded masses and as disseminated particles near the borders of the lenticular masses of the peridotites.

There is but very little carbonate found associated with these rocks, and what has been observed is unquestionably of a secondary origin.

Literature of the Subject.

So far as I have been able to learn, little has been written regarding the origin of the chromite, or, indeed, its special relation and significance to the rocks in which it has been found.

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* J. V. Lewis, *Elisha Mitchell Sci. Soc. Jour.*, vol. xii., Part II., p. 24, and J. H. Pratt, *Am. J. Sci.*, 4th series, vol. vi., July, 1898, p. 51.

It is not the purpose of this paper to give a history of chromite, but simply to state a few facts from other authorities that will bear directly upon the subject under discussion.

In a final report on the geology of Massachusetts (1841), Hitchcock* mentions the chromite as occurring in minute grains through most of the serpentine in Massachusetts west of the Connecticut river, and notes that where the mineral occurs in pockets these are near the eastern portion of the serpentine.

G. H. Cook† in a report on the geology of New Jersey, speaking of the occurrence of serpentine at Hoboken, says that numerous small crystals of chromite are found through the serpentine.

In 1875, C. D. Smith,‡ who had visited the majority of the peridotite exposures in North Carolina, says: "Chromite occurs in the chrysolite rocks throughout the entire range, so far as I have examined it." This is substantially declared also in the report of J. V. Lewis§ on the basic magnesian rocks of western North Carolina. Lewis points out that small octahedrons or rounded grains of chromite or picotite are sparingly scattered through nearly all the peridotite rocks. In describing dunite he says: "Besides chrysolite in dunite, either chromite or picotite, while neither is regarded as an essential constituent, is always present in rounded grains, and occasionally in crystals."

The geological reports of Georgia|| are almost identical in their descriptions of the occurrence of chromite with those of North Carolina. Those of Pennsylvania¶ and Maryland** note the general occurrence of chromite in these States in the "serpentine rocks," and describe more in detail the workable deposits of chromite; but no mention has been found in them of the formation of these ores or their origin.

M. E. Wadsworth,†† in describing the peridotites, mentions

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* *Geol. of Mass.*, Part I., p. 191, 1841.

† *Geol. of N. J.*, 1868, p. 326.

‡ *Geol. of N. C.*, vol. i., 1875; Appendix, p. 106.

§ *N. C. Geol. Survey, Bull.* 11, 1896, p. 18.

|| *Ga. Geological Survey, Bull.* 2.

¶ *Pa. Geol. Survey*, vol. CCC., 1880, and C 4, 1883.

** *Md. Geol. Survey*, vol. i., 1897.

†† *Lithological Studies*, Oct., 1884.

the almost constant occurrence of chromite and picotite in these rocks.

Adams,* at the close of his paper "On the Igneous Origin of Certain Ore-Deposits," says:

> "The uniform character and constant association of chromic iron-ore, wherever deposits of this mineral are found, with serpentine, which rock is a decomposition-product of basic eruptive rocks rich in olivine, point very strongly to the probability of this mineral also being a product of the differentiation of basic igneous magmas during cooling and before their solidification and alteration to serpentine."

This is essentially the idea of Vogt, who says that the deposits of chromite are basic magmatic segregations from peridotite.

In the Seventeenth Annual Report of the United States Geological Survey, Glenn,† under the head of the occurrence of chromite, makes this statement:

> "We now are familiar with the chromic iron deposits of the eastern part of America from the Gulf of Mexico to the St. Lawrence, with the mines of California, from San Luis Obispo to the Washington boundary, and with those of Norway and of the Urals; with the deposits of the Danubian provinces, and of Asiatic Turkey and of Syria, and with those of the Gundagia district of New South Wales. With this knowledge before us, we can say distinctly that, wherever found at all, chromic iron is found in serpentine rocks. It is an impressive fact that chromic iron is found in serpentine only, or in some rock nearly akin to it, and, like it, metamorphic."

In a recent article on chromic iron-ore, J. E. Carne,‡ in speaking of the New South Wales localities, says that all the chromite in that province is found in serpentine.

As has been shown, the deposits of chromite are described as occurring, for the most part, in serpentine, while many of them undoubtedly occur in a peridotite; the term serpentine being loosely used, especially among mining men, for any of the original peridotite rocks and their different alteration-products.

The two non-feldspathic types of eruptive rocks that we have to deal with are the peridotites and the pyroxenites.

Of the first type, those common to North Carolina are:

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* Cited before.

† *U. S. Geol. Survey*, 17th Ann. Rep., 1895–96, Part III., p. 264.

‡ *New South Wales Geol. Survey*, "Mineral Resources," No. 1, 1898.

Name.	Mineral Composition.
Dunite, ...	Olivine.
Harzburgite or Saxonite, .	Olivine and orthorhombic pyroxene (enstatite).
Amphibole picrite, . .	Olivine, amphibole, and usually some pyroxene.

Wadsworth,* in his description of the peridotites, mentions:

Lherzolite, ...	Olivine, enstatite, and diallage.
Buchnerite, ...	Olivine, enstatite (bronzite), and augite.
Eulysite, ...	Olivine and diallage.
Picrite, ...	Olivine and augite.

Another rock from North Carolina usually classified with the peridotites is the forellenstein (troctolite), composed of olivine and the triclinic feldspar, anorthite, with zones of intermediate silicates developed between the two. There is nowhere a direct contact of the olivine with the feldspar, but these are usually separated from each other by a double zone of fibrous minerals, which are arranged at right angles to their borders.

Zones of the same kind have been described by Adams† in the anorthosites of Canada in which the zone adjacent to the olivine corresponds to enstatite, while that adjacent to the feldspar is a fibrous green hornblende.

According to the definition of a peridotite, that it is an olivine rock without essential feldspar, the forellenstein would not belong to this type; but it is classified here on account of its occurrence with dunite, instead of gabbro, with which it is usually found.

The two pyroxenites that have been observed in North Carolina are:

Name.	Mineral Composition.
Enstatite rock, ...	Orthorhombic pyroxene (enstatite).
Websterite, . . .	Orthorhombic and monoclinic pyroxene (bronzite and diopside or diallage).

Alteration of the Peridotites and Pyroxenites.

The two common alteration-products of these basic magnesian rocks are serpentine and talc. The latter is more gener-

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* *Lithological Studies*, pp. 128, 101, 147, 149.

† *N. C. Geol. Survey, Bull.* 11, p. 25 (Lewis).

ally formed from the alteration of the pyroxenites, the pyroxene passing into hornblende, and this into talc. In commenting on the formation of the large deposits of steatite in eastern Maryland and Virginia, the report of the Maryland Geological Survey says:

"This" (changing of pyroxene to hornblende to talc) "is the origin of the extensive beds of steatite in eastern Maryland and Virginia. The talc is always mixed with more or less pale fibrous hornblende (tremolite) and chlorite."

In the alteration of the peridotites the change is materially different, being influenced by the olivine, and the alteration is usually to a serpentine.

Serpentinization is first observed along the borders of the grains of the olivine, increasing until finally the olivine is entirely replaced by the serpentine.

In the peridotites of North Carolina only the earlier stages of serpentinization are at all common, and complete alteration has only been observed in a few small areas.

In the alteration of the peridotite, dunite, the secondary product would be a nearly pure serpentine, while in the alteration of the others, saxonite (harzburgite), buchnerite, picrite, etc., which contain, besides the olivine, some one of the pyroxenes, not only [illegible]. but a series of alteration-products would be found, such as hornblende, talc, chlorite, etc. Besides these alteration-products, there are found small amounts of magnetite, actinolite, and traces of carbonates, and a series of minerals formed by the alteration of the peridotites influenced by the primary minerals, corundum, chromite and spinel, when present in these rocks.

Occurrence and Origin of Chromite.

With the exception of alluvial deposits, chromite has been found only in the peridotites and allied igneous basic magnesian rocks, or in the serpentines which have resulted from the alteration of these rocks. As I have observed the chromite in the North Carolina peridotites, it occurs more commonly in grains or crystals, and also in imbedded masses, near the boundary of the lenticular bodies of these rocks. A noticeable exception to this is near Webster, Jackson county, N. C., where, in addition to the occurrences of some of these imbedded

masses, grains of chromite appear to be disseminated throughout the entire mass of certain portions of the peridotite (dunite).

The mineral does not occur in well-defined veins, but in masses or pockets, which *apparently* have no relation whatever to each other.

But few authors, writing upon the occurrence of chromite, have described the relation of the chromite-deposit to the rocks in which it is found. One or two have mentioned the chromite as being found near the eastern boundary of the serpentine or at the northern border of the serpentine belt; but in no case have I been able to find any definite description. My observations have shown that the large deposits of chromite occur in the peridotite rock, and near the contact of this rock with the enclosing gneiss. Also, that where there is but a small amount of the chromite, either in pockets or in grains or crystals, these are more abundant near the contact, and diminish in number toward the center of the mass of the peridotite.

Where the larger deposits of chromite occur there has been little or no corundum found, and where we find large deposits of corundum there is a scarcity of the chromite.

Crystallized chromite has been found only in small isolated crystals scattered through the peridotite, or where these crystals have been concentrated in alluvial deposits. The masses of chromite show little or no crystalline structure.

In a recent letter from the Maryland Geological Survey regarding the amount of chromite in the peridotite rocks of that section, the following was given:

1. "None of the serpentine or peridotite sections show any noticeable amount of chromite."

2. "Analyses of the peridotite show 0.5 per cent. of chromic oxide."

This constant occurrence of the chromite in rounded masses of varying proportions, near the contact of the peridotite with the gneiss, and its occurrence in the fresh, as well as the altered peridotite, indicate that the chromite has been held in solution in the molten mass of the peridotite, when it was intruded into the country-rock, and that it separated out among the first minerals as this mass began to cool.

As has been said before, the peridotite (dunite) magma,

holding in solution the chemical elements of the different minerals, would be like a saturated liquid; and, as it began to cool, the minerals would separate or crystallize out, not according to their fusibility, but according to their solubility in the molten magma. The more basic portions being, according to the general law of cooling and crystallizing magmas, the less soluble, would therefore be the first to separate out. These would be the oxides containing no silica; in the present case, the chromite, spinel and corundum. These minerals would solidify or crystallize out where the molten magma first began to cool, which would be at the contact of the mass with the country-rock; convection-currents would tend to bring new supplies of material to the outer boundary, which would deposit its chromic oxide as chromite.

The more fluid a molten mass of rock becomes, the more favorable will be the movements and other conditions in this molten mass to the bringing about of these changes; and it is in these very basic magnesian rocks that we find the best illustrations of the separation and concentration of the more basic minerals.

This would account for all the irregularities of the chromite-deposits; their pockety nature; the shooting off of apophyses from the main masses of the chromite into the peridotite; the widening and pinching of the chromite "lodes;" and the apparent non-relation or non-connection of one pocket of chromite with another. There has not been sufficient work done in the North Carolina chrome-mines to demonstrate exactly the position and relation of the chromite deposits to the gneiss or other country-rock; and, in the description of other chrome-mines, but little light has been thrown on this point. However, from what has been observed, my idea of the appearance of a vertical cross-section of the peridotite holding chromite in solution, soon after its intrusion into a gneiss, is represented by Fig. 1. In this figure the zone of chromite has been greatly exaggerated, in order better to represent the cross-section. The chromite would be concentrated near the borders of the peridotite in rounded masses, with offshoots penetrating into the peridotite. The line of contact near the gneiss would be sharp and nearly regular, while, with the peridotite, the contact would be very irregular. The pockets of chromite (I. and

II., Fig. 1), found in the midst of a peridotite formation, which at the present time are isolated and have no connection with each other, were at the time of their formation part of the chromite concentrated near the border of the peridotite; but the rapid erosion to which these rocks have been subjected has worn them down to their present condition, represented by the dotted lines. Again, there would be a somewhat gradual passage from the chromite to the pure peridotite.

FIG. 1.

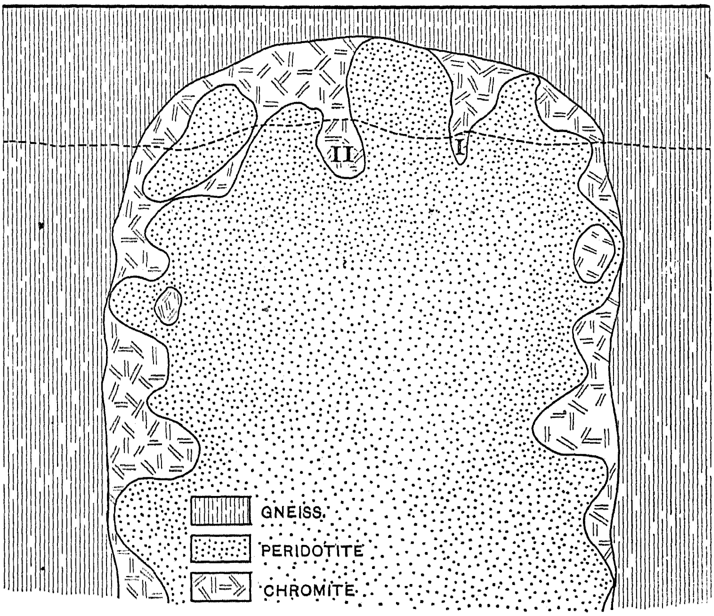

FIG. 1.—An Ideal Vertical Cross-Section of a Mass of Peridotite, soon after its Intrusion into a Gneiss, Illustrating the Irregular Concentration of the Chromite near the Contact. (The chromite zone is greatly exaggerated.)

This cross-section of the occurrence of the chromite is very similar to one described by me as representing the appearance of a contact-vein of corundum soon after its formation. The corundum, however, makes a more sharp and distinct vein, and is usually in contact with the gneiss; while the chromite is very apt to be in rounded masses, often separated from each other by the peridotite, or only connected with each other by narrow seams of chromite.

Figs. 2 and 3 represent the contact of a gneiss and of a

peridotite holding in solution but a small amount of chromite, which separated out as small globular nodules (Fig. 2) or in small particles or crystals (Fig. 3). As is illustrated in the figures, the nodules and particles of the chromite are more abundant near the contact, and diminish in number toward the center of the peridotite.

The laboratory-experiments of Morozewicz and Lagorio, already referred to, together with field-observations, have led me to accept the theory that the chromite was formed at the same time as the peridotite, was held in solution by the molten

FIG. 2.

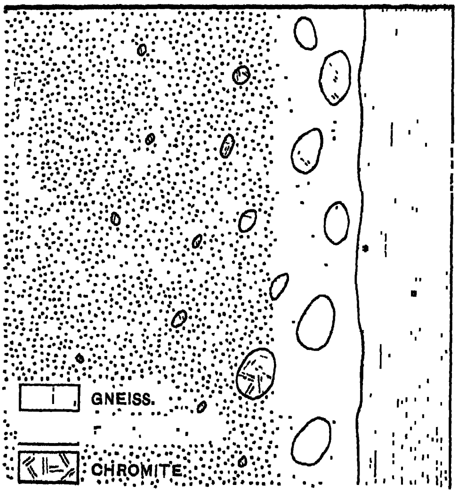

FIG. 2.—Vertical Cross-Section of Peridotite-Gneiss Contact, Illustrating the Concentration of the Chromite Nodules near the Contact.

peridotite, and separated out among the first minerals as this mass began to cool.

In mining for either chromite or corundum, it is in that deposit found near the contact of the peridotite with the gneiss or other country-rock that a large quantity of either of these minerals may be expected to be found.

Conclusions Drawn from the Above Theory.—Chromite has been found only in peridotite and serpentine; and the presence of this mineral in these rocks would at once indicate that the rocks were of igneous origin. We know that some peridotite rocks may be of metamorphic origin; that they might have

been formed by the metamorphosis of dolomitic limestones, containing iron in the form of $FeCO_3$, as in $(MgFe)CO_3$, or beds of siderite rich in magnesia, silica in the form of sand being probably present. Rocks of this type, subjected to great dynamic pressure, in the presence of moisture, would have their carbonic acid nearly completely driven off, and silicates would be formed, perhaps, according to the formula $2MgCO_3 + SiO_2 = Mg_2SiO_4 + 2CO_2$.

If a peridotite rock were formed in this manner, we should expect to find some carbonates associated with it, and we should

FIG. 3.

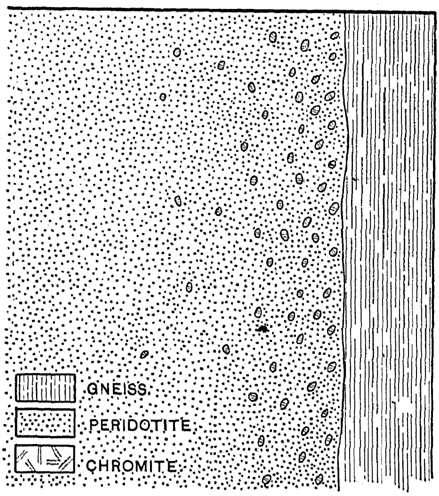

FIG. 3.—Vertical Cross-Section of Peridotite-Gneiss Contact, Illustrating the Concentration of the Particles of Chromite near the Contact. (The particles of chromite are greatly exaggerated.)

not expect to find any chromite or spinel. On the other hand, when chromite or spinel are present, and there is an absence of carbonates, it is a strong indication that the peridotite is of igneous origin.

Wadsworth,* in his *Lithological Studies*, already referred to, says:

"That serpentines are produced from the alteration of peridotic rocks is the testimony of all lithologists who have studied their structure with the microscope, and it is one of the most fixed facts in science. That serpentines are not

* p. 190.

produced in other ways may, perhaps, be looked upon as an open question at the present time, although there would seem to be no proof of any other mode of origin."

The field-facts obtained point also to this conclusion, and strengthen the view that all serpentines are alteration-products of some peridotite or allied rock.

Chromite has been observed *in situ* only in peridotites of an igneous origin; and it is not probable that this mineral is to be found in serpentine resulting from the alteration of a metamorphic peridotite rock. Thus the theory advanced for the origin of chromite will cover all the known occurrences of this mineral.

The large deposits of chromite in the serpentine rocks of Pennsylvania and Maryland show that the primary rock was of igneous origin, and that the mineral solidified out from the molten magma, as described above.

A natural corollary to be drawn from this proposition is that the occurrence of chromite in an alluvial deposit indicates the proximity of a peridotite rock of igneous origin, which was the original source of the chromite.

In the September (1898) number of the *American Journal of Science*, G. C. Martin describes the occurrence of a dunite formation in the western part of Massachusetts. The presence of chromite in this rock and the absence of any carbonates indicate to me the igneous origin of this dunite.

The association of platinum with chromite and serpentine, in various parts of the world where platinum has been found in alluvial deposits, indicates that the origin of the platinum is a peridotite or allied rock of igneous origin. On the eastern slope of the Urals platinum has been found associated with chromite, which is disseminated through an olivine rock.

It is not unreasonable to suppose that platinum will be found in the peridotite areas of the United States. Platinum has been reported from North Carolina; but no authenticated record of this occurrence can be obtained. It is to be hoped, however, that in the near future, an occurrence of platinum in this State may be proved.

Chemical Composition of Chromite.

Chromite has been analyzed from the following localities in

North Carolina: Price's Creek, 6 miles southwest of Burnsville, Yancey county; Webster, Jackson county; and Corundum Hill, Macon county.

Pure material for analysis, showing no impurities when examined with the microscope, was readly obtained by hand-picking.

The mineral was fused several times with bisulphate of potash, then taken up with hydrochloric acid and tested for silica. Iron, aluminum and chromium were precipitated with ammonia, the precipitation being made at least three times. Magnesium, calcium and manganese were determined in the filtrates by the usual methods.

The precipitate of the mixed oxides was dissolved in hydrochloric or nitric acid, and the excess of the acid evaporated. Sodium hydroxide was then added in excess, and chlorine was passed into the hot solution. The solution was acidified, and the iron and the aluminum were precipitated twice with ammonia and weighed as mixed oxides. These oxides, containing a trace of chromium, were fused with acid potassium sulphate, digested with water and acidified. One precipitation was made with ammonia to partially remove sulphates, and the precipitate was dissolved in hydrochloric acid and treated as before, the iron and aluminum being obtained free from chromium. The iron was determined volumetrically.

To the filtrates containing the chromium, alcohol and hydrochloric acid were added, and the solution was digested for some time. The chromium was precipitated as hydroxide and weighed as Cr_2O_3. To insure the purity of the precipitate, it was fused with 4 parts of sodium carbonate and 1 part of potassium nitrate; the fusion was taken up with water and tested for magnesia.

A number of experiments were made to determine the ratio of ferrous to ferric oxide, but they were all unsatisfactory. By digesting the very finely powdered mineral in a mixture of hot concentrated hydrofluoric acid and sulphuric acid, in an atmosphere of carbon dioxide, for half an hour, enough of the mineral was decomposed to show the presence of ferric oxide.

The analyses I. and II. were made by Dr. Charles Baskerville, of the chemical laboratory of the North Carolina Geo-

logical Survey, and III. by Dr. H. W. Foote, of the Sheffield laboratory, Yale University.

The results of the analyses were as follows:

	I. Price's Creek.	Ratio.	II. Corundum Hill.	Ratio.	III. Webster.*	Ratio.
Cr_2O_3,	59.20	.386	57.20	.377	39.95	.261
Al_2O_3,	7.15	.070	7.82	.076	29.28	.287
FeO,	25.02	.347	25.68	.356	13.90	.193
MgO,	4.42	.111	5.22	.131	17.31	.433
SiO_2,	3.20		2.80		......	
MnO,	0.92		0.69		......	
	99.91		99.41		100.44	

In the above analyses the ratio of the bivalent oxides to the trivalent oxides is uniformly high, and can probably be accounted for by the circumstance that some of the iron calculated as FeO was in the ferric state, as was proved in the Webster chromite.

Taking enough of the Cr_2O_3 and MgO to unite with the FeO and Al_2O_3, respectively, to form the molecules FeO, Cr_2O_3, and MgO, Al_2O_3, there remains approximately enough of the Cr_2O_3 to unite with the excess of MgO. The nearer the ratio of the bivalent oxides equals that of the trivalent, the nearer the excess of Cr_2O_3 and MgO equalize each other. The inability to determine the ratio of ferrous to ferric oxide in the above analyses prevents the obtaining of a sharp ratio in the excess of the Cr_2O_3 and MgO.

In all the terrestrial chromite-analyses examined, with the exception of two, alumina and magnesia were invariably present, varying from a small percentage in some analyses to more than 20 per cent. in others. In the above analyses, and in most of the others, it was noticed that the alumina usually varied with the magnesia; those rich in magnesia being correspondingly rich in alumina.

This constant occurrence of magnesia and alumina in the chromites would seem to indicate that the molecule of the mineral we now call chromite is not pure FeO,Cr_2O_3, but a combination of the three isomorphous molecules, FeO, Cr_2O_3; MgO, Cr_2O_3 and MgO, Al_2O_3.

* This analysis is of a peculiar chromite, and does not represent the ordinary chromite that occurs in this vicinity (see page 39).

The record of but two analyses of chromite (terrestrial) has been found that does not show the presence of magnesia and alumina. The first was a magnetic chrome-sand from Chester, Pa., analyzed by T. H. Garrett,* in which all the iron is calculated as ferric oxide; and the second, chromite from Vache Island, West Indies, analyzed by J. Clouet.†

	I. (Garrett.)	II. (Clouet.)
Cr_2O_3.	41.55	51.53
FeO,	....	48.46
Fe_2O_3,	62.02	....
SiO_2,	1.25	....
	104.82	99.99

A greater part of the iron in Garrett's analyses is undoubtedly in the form of ferrous oxide, as is indicated by the high total percentage (104.82) obtained. Garrett also analyzed a massive chromite from near Chester, Pa., which showed only the presence of Cr_2O_3, FeO and a little NiO.

From the above it is seen that a pure chromite, having the composition of FeO, Cr_2O_3, is not common in nature. The chromite in meteorites is very generally supposed to be nearly pure FeO, Cr_2O_3; but only one analysis can be found of meteoric chromite. This was made by J. Lawrence Smith‡ upon chromite found in one of the Butcher meteorites from Coahuila. The result of the analysis was Cr_2O_3, 62.71 per cent.; FeO, 33.83 per cent., with traces of magnesia, cobalt and silica. Dr. Smith says: "The magnesia and silica doubtless came from a siliceous mineral," observed to be intimately associated with the chromite, "which is either enstatite or olivine."

This occurrence of chromite is interesting, as associated with a meteorite composed mostly of iron.

The magnesium aluminate, MgO,Al_2O_3, occurs nearly pure in nature as normal spinel. The normal magnesium chromate has not been found in nature; but, as indicated from the above analyses, there is good reason to believe that this molecule does exist, and we may expect to find normal MgO,Cr_2O_3 occurring in nature as a definite mineral.

* *Am. J. Sci.*, 1852, 2d series, xiv., 47.

† *Ann. Chimie et Phys.*, 1869, (4), xvi., p. 93, and *Lithological Studies* by M. E. Wadsworth, page iv. of Appendix.

‡ *Am. J. Sci.*, 3d series, xxi., June, 1881, p. 462.

Under this theory of the composition of the chromites, the formulas of the three described in this paper would be as follows:

1. Price's Creek, $10(FeO,Cr_2O_3)$; MgO,Cr_2O_3; $2(MgO,Al_2O_3)$.
2. Corundum Hill, $9(FeO,Cr_2O_3)$; MgO,Cr_2O_3; $2(MgO,Al_2O_3)$.
3. Webster, FeO,Cr_2O_3; MgO,Cr_2O_3; $2(MgO,Al_2O_3)$.

The first two formulas will represent approximately those of the majority of the chromites that have been found, and approach the normal chromite FeO, Cr_2O_3 as their limit.

As the FeO,Cr_2O_3 molecule decreases, and the MgO,Al_2O_3 increases, the mineral would approach normal spinel MgO,Al_2O_3 as its limit, the mineral picotite or chrome-spinel being representative of a mineral near the spinel end.

Dr. Wadsworth, in comparing the chromite and picotite associated with peridotites, says:

"It is probable that picotite and chromite belong to the same mineral series, the term picotite being more commonly applied to the freshest states, and that of chromite to those forms more altered, and to the local aggregations arising from the migration of the chromic oxide during the alteration of the associated peridotite rocks."*

"As a further extreme in the alteration, a change to a more or less pure magnetite occurs."†

These conclusions of Dr. Wadsworth are deduced from a microscopical study of the minerals.

I do not agree with him that the chromite represents an altered product of a mineral, of which picotite is a purer form. The chromite is a mineral which suffers alteration but slightly, and, as it is found at the present time, represents the original mineral and not an altered form. The difference in the microscopical properties can readily be accounted for by the chemical composition. With an increase in the ratio of the molecule, MgO,Al_2O_3, and a corresponding decrease in the molecule, FeO,Cr_2O_3, the more translucent the mineral will become.

These two minerals belong to the same group, and are closely allied to each other; and they represent two primary minerals, and not different stages in the alteration of another mineral. All the analyses that have been examined of the mineral classified as picotite are nearly uniform in their composition, and are decidedly different from those of chromite.

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* *Lithological Studies*, p. 184. † *Geol. Surv. of Minn.*, *Bulletin* 2, 1887, p. 28.

The three following analyses will illustrate the general composition of this mineral:

	*I.	†II.	‡III.
Al_2O_3,	55.34	52.47	50.34
Cr_2O_3,	7.90	7.01	5.75
FeO,	24.60	21.42	22.27
MgO,	10.18	18.23	17.87
SiO_2,	1.98	1.25	3.77

It will be noticed in these analyses that the alumina is very high, and the chromic oxide correspondingly low; and this is characteristic of all the mineral matter classified as picotite.

In the analysis of the Webster chromite, the largest percentage of MgO was obtained; and in the calculation of the ratios, the formula was shown to be FeO,Cr_2O_3; MgO,Cr_2O_3; $2(MgO, Al_2O_3)$; this being the highest ratio of the molecule MgO,Cr_2O_3 in any chromite examined. The theoretical composition is here given, together with the analysis of the Webster mineral:

	Webster Chromite. Found. Per cent.	Theoretical per- [illegible] Cr_2O_3.
Cr_2O_3,	39.95	40.90
Al_2O_3,	29.28	30.44
FeO,	13.90	10.75
MgO,	17.31	17.91
	100.44	100.00

This analysis is similar to that described by Bock§ for the magnochromite from Grochau, Silesia, which contained Cr_2O_3, 40.78; Al_2O_3, 29.92; FeO, 15.30; and MgO, 14.00.

In appearance this Webster chromite is different from any that have come under my observation, being much more coarsely granular than the ordinary chromite.

As picotite represents a variety of spinel, the pure MgO,Al_2O_3, we can consider this Webster mineral as a variety of a mineral to be discovered, having the theoretical formula MgO,Cr_2O_3, or of normal chromite FeO,Cr_2O_3.

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* L. Lherz, France, *Wadsworth's Lithological Studies*, p. ii, Appendix.

† Kosakover, Bohemia, *Wadsworth's Lithological Studies*, p. ii, Appendix.

‡ Kosakover, Bohemia, *Wadsworth's Lithological Studies*, p. ii, Appendix.

§ *Zeits. Deutsch. Geol. Ges.*, 25, 394, 1873.

In order to designate this Webster chromite, and others of similar composition, I propose the name *mitchellite*, in honor of the late Prof. Elisha Mitchell, of North Carolina.

CHROMITE IN NORTH CAROLINA.

Extending from Ashe county to Clay county, N. C., there is a series of disconnected peridotite outcrops; and, as has been observed above, chromite is associated with all these peridotite rocks. It is, however, in few localities only that the mineral has been found in considerable quantity. Although prospecting for chrome-ore in this State was first undertaken over thirty years ago, and has been continued spasmodically ever since, there has never been any systematic development of the localities.

In the alluvial deposits at the base of the peridotite outcrops there is usually a considerable amount of chromite crystals and particles, but nowhere have they been observed in sufficient quantity to constitute a chrome-sand ore.

Many of the titaniferous iron-ores* of the State contain a little chromic oxide.

The general character of the chrome-ore is nearly uniform throughout the entire area, being very hard and compact, though often of a fine granular appearance, and there is but little that is at all friable.

The masses of chromite are usually very free from seams of peridotite or its alteration-product, serpentine. This simplifies the concentration, and a high-grade ore can usually be obtained by cobbing and hand-picking.

In the following descriptions of localities, only those are mentioned in which the chromite occurs otherwise than in grains or small nodules; and a full description is given of the localities only in which the ore is found in quantity.

In Watauga county, Nitze† mentions the occurrence of chromite in small pockets or seams in the drainage-basin of Cove creek, 7 miles N.W. of Boone.

On the farm of David Lawrence a pocket of chromite was

* *N. C. Geol. Survey, Bull.* 1, p. 229.

† *N. C. Geol. Survey, Bull.* 1, p. 212.

opened that yielded about 10 tons of ore. When this pocket had been exhausted, no further prospecting was undertaken.

In Yancey county, one of the two more important deposits in the State occurs at Mine hill on the Mine fork of Jack's creek, 5 miles N. of Burnsville, the county-seat, on the Bakersville road, where a large peridotite (dunite) formation outcrops on both sides of the road. In this peridotite, seams or pockets of chromite-ore are very abundant, varying from 0.5 to 3 inches in thickness. Near the summit of the hill, on the east side of the road, about 150 feet above the road and stream-bed, a deposit of chromite has been opened, from which 25 tons of ore were taken, a large part of which still remains on the dumps. A pit 9 feet deep was sunk on the deposit; but this has been filled with water since the work ceased, so that no estimate can be made of the extent of this deposit. Garrett Ray, the owner, reports that the chromite was between 2 and 3 feet wide at the bottom of the pit, having broadened out nearly 2 feet in the depth of the pit. There are other promising seams or veins which appear to indicate the existence of a large deposit of chromite-ore near the contact of the peridotite and gneiss.

On the west side of the road, the peridotite formation rises in another hill, and here there are numerous small seams and pockets of chromite. On the extreme western slope of the formation a trench has been cut 100 feet or more into the hill, in which are exposed many small pockets of chromite. The work done in this trench is of a prehistoric character, and whether the object of the exploration was chromite or not has never been explained.

This is perhaps the most promising region in the State for a large deposit of chromite.

With the exception of the pit sunk near the summit of Mine hill, from which a few tons of ore were shipped, there has been no mining carried on here; and very little prospecting has been undertaken to determine the exact extent of the chromite-deposits.

The distance from the railroad has very greatly discouraged systematic prospecting in this region. The present shipping-point is Asheville, on the Southern Railroad, about 40 miles to the south, over a fair mountain road. The nearest railroad-

point is Erwin, Tenn., on the Ohio River and Charleston Railroad; but although the distance (27 miles) is much shorter, the railroad facilities are not at the present time as good as those at Asheville.

The property is owned by Garrett D. Ray, of Burnsville, Yancey county, N. C.

An analysis of a selected specimen of the chromite (Baskerville, analyst,) gave:

	Per cent.
Cr_2O_3,	58.00
Al_2O_3,	15.52
FeO,	14.45
MgO,	8.26
SiO_2,	3.20
CaO,	.70

Although this analysis represents a selected sample of the chromite, yet from the character of the material it is not unreasonable to expect an ore that, by hand-picking and cobbing, will assay in the neighborhood of 52 per cent. of chromic oxide, with a low percentage of silica.

About 9 miles west of Burnsville, near Price's creek, there is a narrow bed of peridotite on the land of W. A. Robertson, a quarter of a mile from Price's Creek Post Office.

A pocket of chromite, discovered here, yielded nearly 7 tons of ore. This exhausted the pocket, and since then no prospecting has been done in this vicinity.

An analysis of a selected sample of this ore (Baskerville, analyst,) gave:

	Per cent.
Cr_2O_3,	59.20
Al_2O_3,	7.15
FeO,	25.02
MgO,	4.42
SiO_2,	3.20
MnO,	.92

In Jackson county, in the vicinity of Webster, there is a large peridotite (dunite) formation extending from about half a mile north of the town to a mile and a quarter south. The widest part of the area, about half a mile, is at Webster, the town being partly built on the dunite hill. The Tuckaseegee river cuts through this formation about half a mile below the town.

Considerable prospecting has been carried on in this region, and numerous veins and pockets of chromite, of varying extent, have been discovered.

The only deposit of any note found on the north, or Webster, side of the river is on the east side of the Tuckaseegee road, about 200 yards from the main street of the town, on the land of Daniel Schneider. A pocket of chromite was uncovered here which yielded a number of tons of chromite, most of which was shipped. At a depth of nearly 9 feet the pocket pinched out, leaving but a small seam of chromite in sight. Many small seams and pockets of chromite are to be seen, but no other work has been undertaken for chromite on this side of the river.

On the south side of the river, following near the contact of the dunite with the gneiss, a line of prospect-pits has been dug which shows the presence of a considerable amount of chromite. The prospecting has been done on the lands of Joseph Hooker, Lawrence Buress, Alf Wilson, James Ashe and Daniel Fullbright, all of Webster, N. C.

The most promising deposits are: one on the land of James Ashe, where a cut 25 feet long, 6 to 8 feet wide and 8 to 10 feet deep, was sunk on a vein of chromite 12 to 18 inches wide, which, at the bottom of the cut, is 12 inches in width; and another on the land of Daniel Fullbright, where a seam nearly 12 inches wide is exposed in the branch. The nearest shipping-point is Sylva, on the Southern Railroad, 3 miles north of Webster.

The North Carolina ores are all of high grade, but the existence of large deposits has not yet been conclusively shown. What work has been done, however, points to the probability of large deposits of chromite in this State, especially at Mine hill, Yancey county, and possibly at Webster, Jackson county, these two being the most promising localities.

A Geologic and Economic Survey of the Clay-Deposits of the Lower Hudson River Valley.

BY CLEMENS CATESBY JONES, B.S., RICHMOND, VA.

(New York Meeting, February, 1899.)

THE substance of this paper, now amended and altered in form for its present use, was the basis of a private report prepared under professional engagement.* A private report is necessarily objective, and deprived of the scope and technicality of a scientific treatise—which accounts for the prevalence of drawings and succinct mathematical statements rather than full descriptive details in a paper reproduced from data, of which all the original working-notes have been destroyed.

In a practical sense the Hudson river valley clay-deposits owe their present existence to the protection afforded by the rock-formations on which they are supported, and, instead of being uniform in depth or continuity, are subject to the irregularities of the rugged masses which preceded and are now concealed by them. The only available information concerning these deposits contained in previous public reports or maps furnished at best a mere photograph of the surface, and as now apparent this was misleading or unreliable. It was the object of this investigation to determine in a practical manner the location, form and extent of all the clay-deposits at present existing in the lower Hudson river valley, and to ascertain with a

* My report was made to Oakleigh Thorne, Esq., of New York City, as the head of a large syndicate, to whose judgment, enterprise and liberality the origin and conduct of the expedition is indebted. Field work was begun October 25th, and completed December 14, 1897. A steam-yacht, with a 30-foot launch as tender, was chartered for the expedition. The aides were as follows:

D. Dana Luther, Naples, N. Y., Assistant N. Y. State Geologist.

Aaron Deane, Jr., C.E., Rahway, N. J.

W. R. Schofield, Fishkill-on-Hudson, N. Y.

A. L. Francisco, C.E., Easton, Pa.

Five assistants were assigned to the aides, and the boring gangs consisted of one foreman and twenty-one men. Mr. Francisco was stricken with typhoid fever while in service and did not recover in time to rejoin the expedition.

reasonable degree of accuracy the available quantity of a clay contained in them, and its suitability for the manufacture of common building-bricks.

The work comprised, therefore, these departments: exploration, to locate the clay-deposits; survey, to identify them, and testing, to define them. The working-force was correspondingly divided into the party of exploration, or reconnoissance, the surveying party, and the boring-gangs.

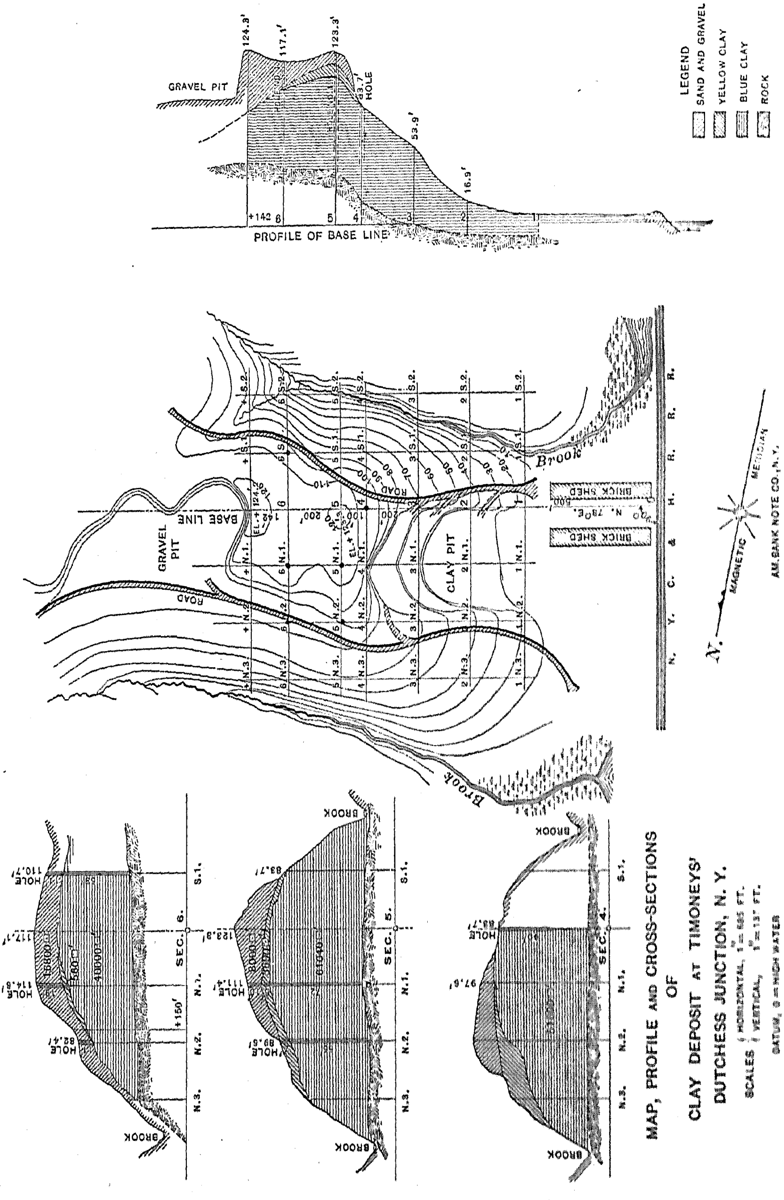
Methods of Work.

Exploration.—Exploration was conducted in the field in advance of the other working-parties. This was done progressively, by moving slowly up the river by launch, examining all the formations exposed along the banks, and landing wherever expedient, to closely study the local geology, or that of the adjoining country. This work was greatly assisted by the excellent State topographical maps of the sections under examination. Wherever clay-deposits or shales were indicated by this reconnoissance a careful exploration was made, and all debatable territory was selected for survey and exploitation by the several working forces. An exposure of clay, no matter how limited in extent, was subjected to the same scrutiny as a bank known to be large. All terrace-formations were examined with extreme care. In this manner both banks of the Hudson were examined from the point of the first appearance of clay below Croton Point to the concluding territorial limit established above Roseton.

Survey.—After a clay-deposit had been located, the engineers took the field to mark the location for further examination. A base-line was established, generally as near as possible to the longest axis of the deposit, with bearings, courses, etc., as shown by the accompanying maps. This line was run from south to north, to conform to the direction of operation, and its extremities were tied into the outer rail of the railroad-track, as the most accessible line of reference. Accurate measurements were taken. As a rule, property-lines were disregarded, except to indicate, wherever possible, the approximate intersection with the base-line. At right-angles to the base-line, and at intervals of 200 feet, lateral lines were run to cover the full terrace-extension east and west of the base-line.

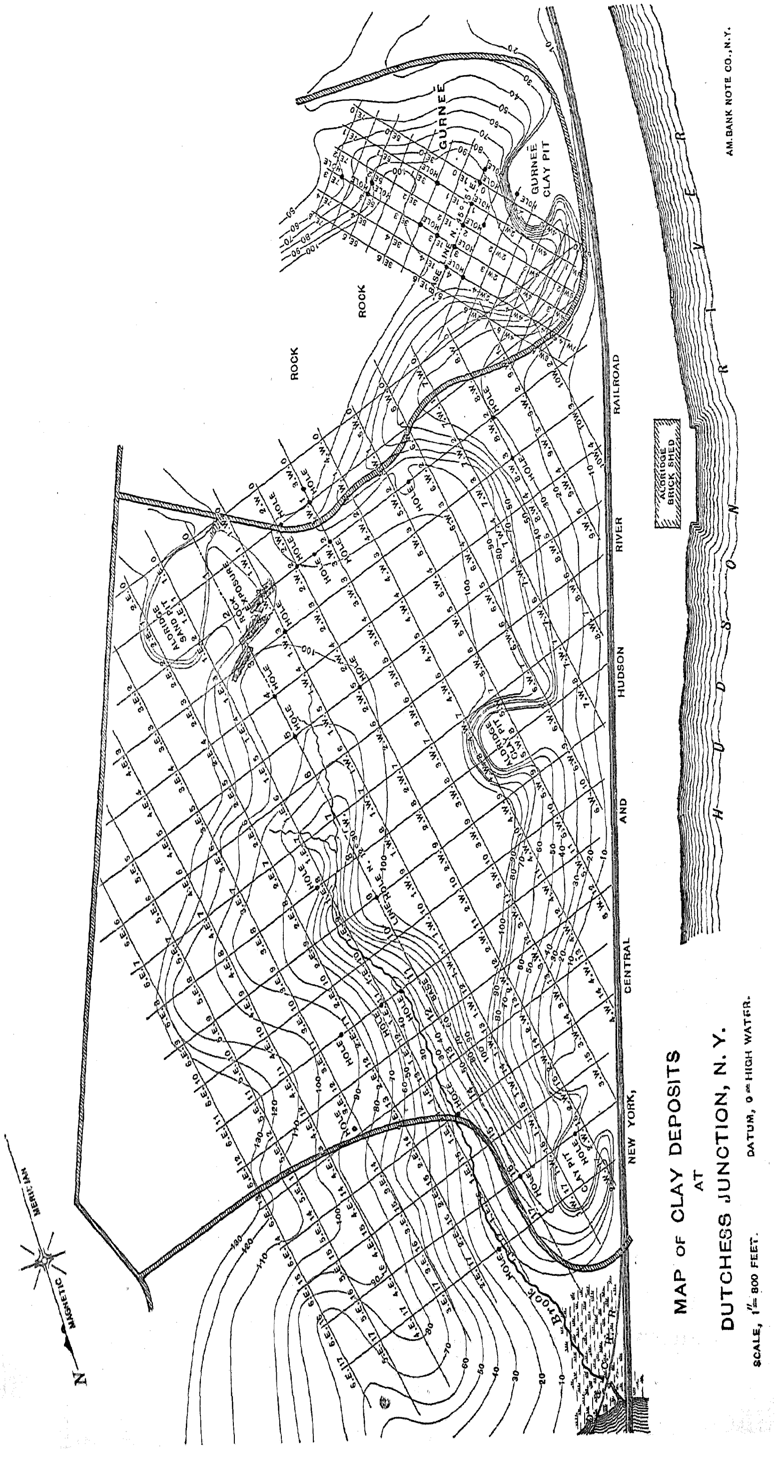
Stakes properly lettered and numbered were driven at all intersections, and elevations were taken at each stake, as well as on all intersecting and measured contours. All the exposed

FIG. 1.



faces of clay-pits were measured, and, when possible, all benches (some of which are very large) were included, so as to give fair measurements for the calculation of contents. Ex-

FIG. 2.


MAP OF CLAY DEPOSITS
AT
DUTCHESS JUNCTION, N. Y.
SCALE, 1" = 800 FEET.
DATUM, 0 = HIGH WATER.
AM. BANK NOTE CO., N.Y.
HUDSON RIVER
NEW YORK, CENTRAL AND HUDSON RIVER RAILROAD
ALDRIDGE BRICK SHED
GURNEE
GURNEE CLAY PIT
ALDRIDGE SAND PIT
ROCK EXPOSURE
ROCK
BASE LINE
MERIDIAN
MAGNETIC
N

amination of the maps and sections will make clear the whole method of operation.

Boring.—Ordinary wood-augers, welded to black iron pipe, were used in boring the test-holes. The augers varied in size from 1- to 2-inch diameter of cutting-face, and were connected by ordinary couplings with half-inch- or inch-pipe in 6- and 12-foot sections, respectively. Each drilling-gang was supplied with 1 20-foot hoisting-gin, 1 6-inch block-and-fall, 100 feet of ¾-inch rope, 1 differential chain-block, 2 augers, 2 handles, 3 pipe-wrenches, 12 feet of 1¼-inch iron rod, 102 feet of pipe in 6- and 12-foot sections, from 20 to 50 feet of 1½- or 3-inch pipe for casing, 1 rock-drill, chains, etc. The portable hoisting-gin was arranged to fold together, so as to be used as a platform on which to carry all the pipe, supplies, etc., lashed to it with rope, and could be easily borne by four men. Three men were assigned to a gang, the foreman of the gangs being the fourth, when a removal was to be made. The borings were regularly inspected as the auger was drawn to the surface, and a record was kept of the depth and variation of all materials encountered. This part of the work was under the charge of Mr. Luther. The depths of the holes varied from a few feet to more than 100 feet. About 150 holes were sunk, each gang averaging one hole per day for the entire time. The bore-holes are all shown on the plans and cross-sections of the different localities, and furnish positive evidence concerning the strata otherwise unexposed or inaccessible. By this means the character of the material, as well as the depth and extent of the deposit were readily ascertained. The limits of the deposits, thus determined, were used, in connection with the exposed face, to define each clay-deposit, and from these data, which permitted a reasonably accurate approximation, the cubic contents were computed. In intermediate cross-sections, where test-holes were not drilled, corresponding depths were interpolated from cross-sections already thus determined.

In advancing the boring-gangs, immediately succeeding sections were omitted when the already accumulated data indicated uniformity of depths, *i.e.*, alternate cross-sections were first bored. If irregularities were discovered, the intervening cross-sections were always tested.

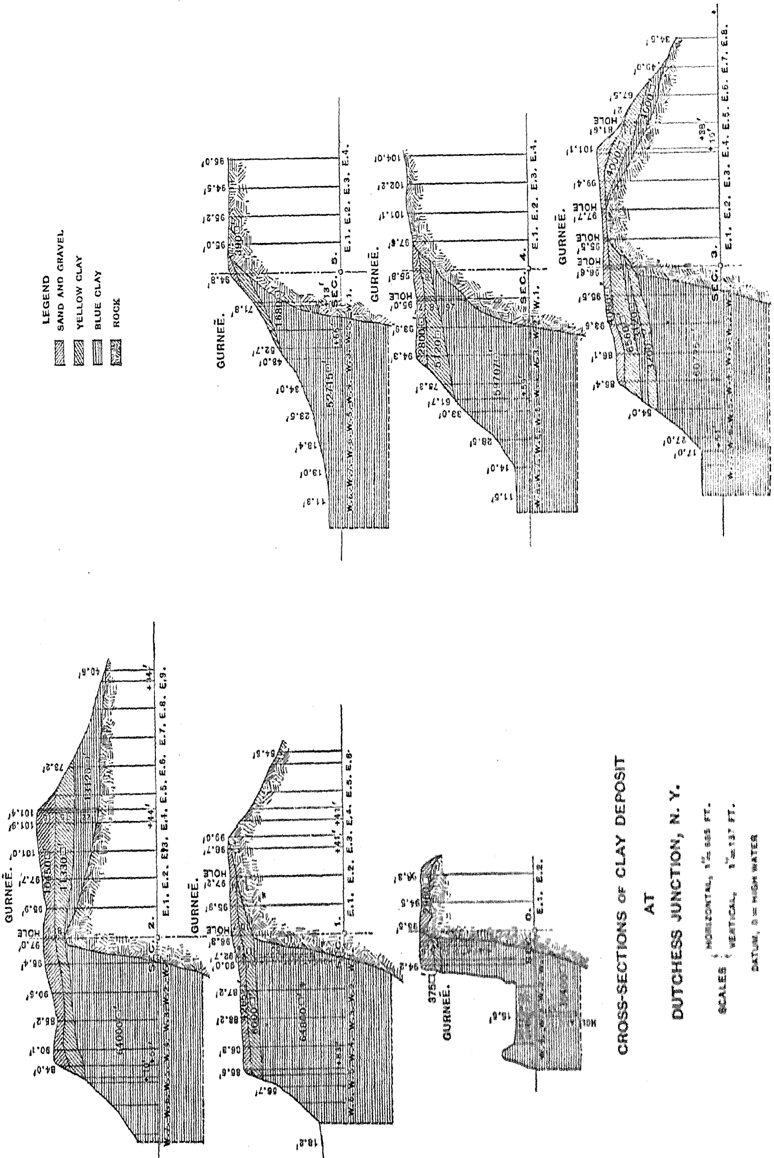
Method of Boring.—As the success of deep boring depends as much upon the apparatus as upon the method of employing it, a detailed account will be found serviceable.

The gin is made of three pieces of good timber—spruce preferably—4 inches by 4 inches by 20 feet in size. The top of each piece is chamfered and a bolt is inserted to prevent splitting. The middle piece is, of course, chamfered on two sides, and the others on the inside only. This is to allow for the spread of the legs of the tripod, or gin, when it is set up. On the chamfered face, below the bolts, a hole is bored in each piece for a $\frac{3}{4}$-inch round iron bar to pass freely. The tops of the three timbers, or legs of the gin, are placed together; the bar is inserted through the hole in the first leg, through one eye of the bail, through the hole in the middle leg, through the other eye of the bail, and then through the hole in the third leg. One end of the iron bar is provided with a squared head, and the other with a slot, into which a pin or dowel is driven, after inserting the bar through the third leg. The bail, of $\frac{3}{4}$-inch round iron, thus hangs on the bar in the spaces between the legs of the gin. The "drop" of the bail should allow it to pass freely over the top of the middle leg, *i.e.*, the length of the bail should exceed the distance from the bar to the top of the timber. Sufficient play should be given in all these parts to have them fit loosely, and washers should be used to protect the wood.

Cleats are nailed to the middle leg of the gin to form a ladder to the top when erected. To erect the gin the middle leg is turned about the bolt as a hinge, until it again lies on the ground. Three men grasp each a leg of the gin, and by pushing towards the bail raise it in a minute. This single maneuver suffices to erect the gin over an exact point. To dismount it the middle leg is simply carried out until the gin is lowered to the ground; this leg is swung back over the bolt again and thus forms the platform upon which everything is carried forward by a single trip, as above described, to the next point of operation. As soon as the gin has been erected, one man ascends the ladder and hooks the wooden block over the bail, and the fall is plumbed over the exact point for the bore-hole. This is an important particular, to insure always a

vertical stress in withdrawing the auger. The rope and fall are now caught up on one of the cleats to the side.*

Fig. 3.

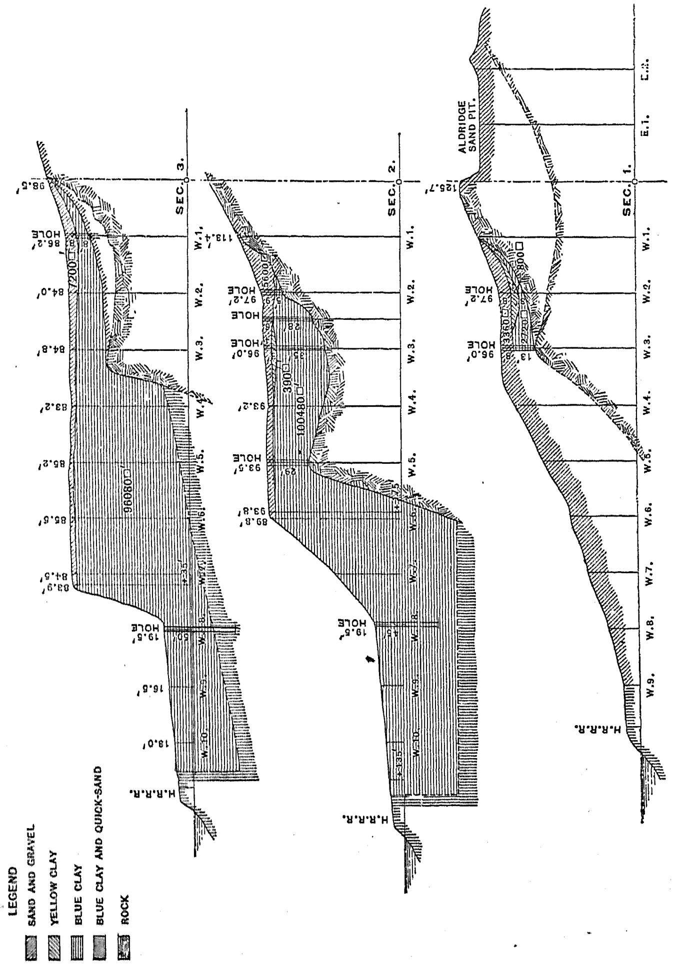


The auger is made from an ordinary wood-auger with 2-inch cutting-face, which is welded to a short piece—about 18 inches

* In the main, unless otherwise specified, I have followed the details given by Mr. Catlett in his paper on "The Hand-Auger and Hand-Drill," etc., *Trans.*, —ii, 123

—of black pipe, on one end of which a thread is cut. This makes the bit about 3 feet long. The handle is about 2 feet long over all, and is made of two pieces of ¾-inch round iron, welded to a strong cylindrical ring, which will pass freely over couplings for 1-inch black pipe. The ring is provided with a

FIG. 4.



CROSS-SECTIONS OF CLAY DEPOSIT AT DUTCHESS JUNCTION, N. Y.

SCALES { HORIZONTAL, 1″ = 685 FT. VERTICAL, 1″ = 137 FT.

DATUM, ^ = HIGH WATER

strong ⅝- by 2½-inch set-screw, for securing the handle to the pipe. The differential chain-block is Yale and Towne's ¼-ton capacity, single-chain. Stillson pipe-wrenches are used, two 18-inch and one 14-inch, and a small monkey-wrench is required for the set-screw. The section of 1¼-inch iron rod has threads cut at each end for 1-inch pipe-couplings. The five 12-

foot sections and seven 6-foot sections of 1-inch pipe have threads cut at each end for couplings. Each section is provided with a coupling at one end, and it is good practice to have a string of extra couplings on hand.

The $1\frac{1}{4}$-inch or 3-inch pipe for casing is in 4 feet or 5 feet sections, with threads cut at each end for couplings. This casing is driven down when troublesome sand or gravel is encountered near the surface. As a rule it is little employed; but in some localities it is an absolute necessity.

The drill is 18 inches long with a 2-inch cutting face, and a thread cut at the other end for 1-inch couplings. It is made from $1\frac{1}{4}$-inch octagon-steel.

The chains, of $\frac{3}{8}$-inch iron, with short links, are 3 feet long, and have heavy rings at one end and hooks at the other.

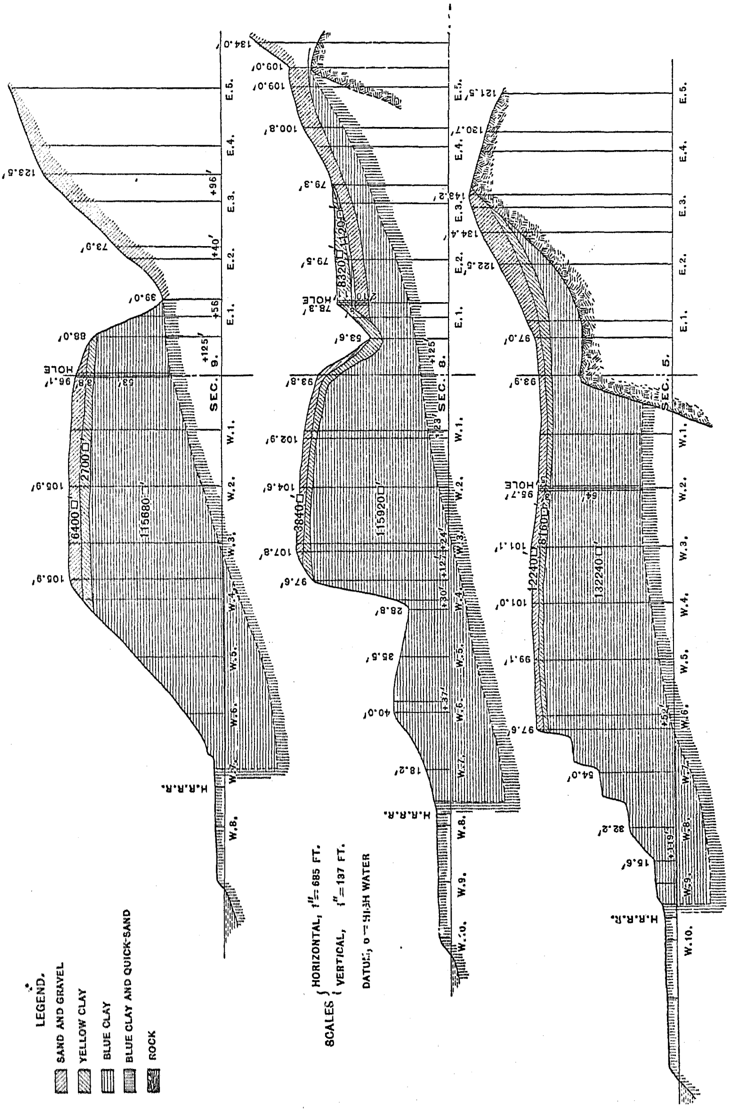
An oil-can and a small file, both for couplings, about complete the outfit for each boring-gang.

In addition to this, a single outfit complete, exactly like the foregoing, but made of $\frac{1}{2}$-inch pipe, the auger and drill having 1-inch cutting-face, will be found indispensable. This can be taken from gang to gang as required. It sometimes happens that a bore-hole made by the larger apparatus becomes unexpectedly obstructed (say, at 50 to 70 feet) by a pebble, a coupling accidentally dropped in, or some other unfortunate cause, and all efforts at progress fail. This smaller apparatus can then often be successfully [illegible] to pass the obstacle and complete the test.

In commencing operations, an auger is attached to a 12-foot section, the handle is [illegible] and boring is begun at a designated point, great care being taken to start vertically, and to preserve the original orifice. Neither more nor less than five turns of the auger are required. This fills the bit, which is then drawn to the surface. One man is always required to attend to the bit, as it enters or emerges from the hole—an insignificant but important duty. As the hole deepens additional sections are attached, until the assistance of the gin is required. At this period, after the auger has received the prescribed number of turns, the set-screw in the handle is loosened and the handle is allowed to drop to the ground. A 3-foot chain is passed around the pipe, the hook being passed through the ring to form a running noose; the hook is attached to the fall,

and stress is applied. After lifting the pipe to a convenient height it is gripped at the ground, either with a wrench or by simply tilting one end of the handle so that the ring binds against the pipe. The stress is released on the chain as soon

FIG. 5.

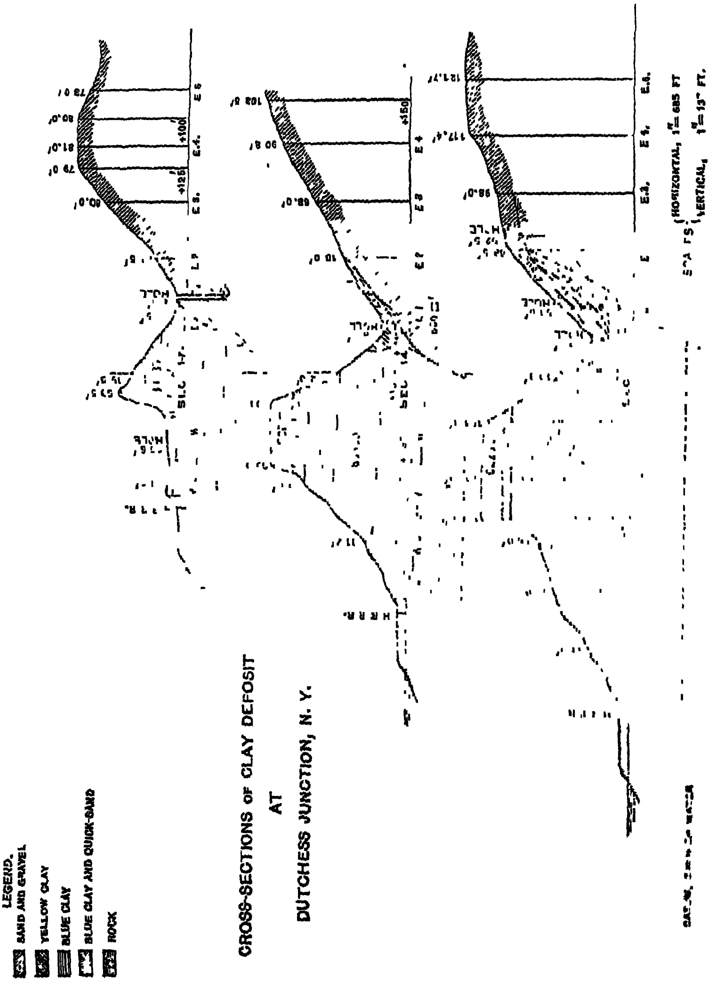


CROSS-SECTIONS OF CLAY DEPOSIT, AT DUTCHESS JUNCTION, N. Y.

as the pipe is held by the grip and the chain slipped down for a fresh hold, continuing in this manner until the auger has been completely extracted. When the depth reaches 30 feet (or for every five 6-foot sections), the column of pipe must be discon-

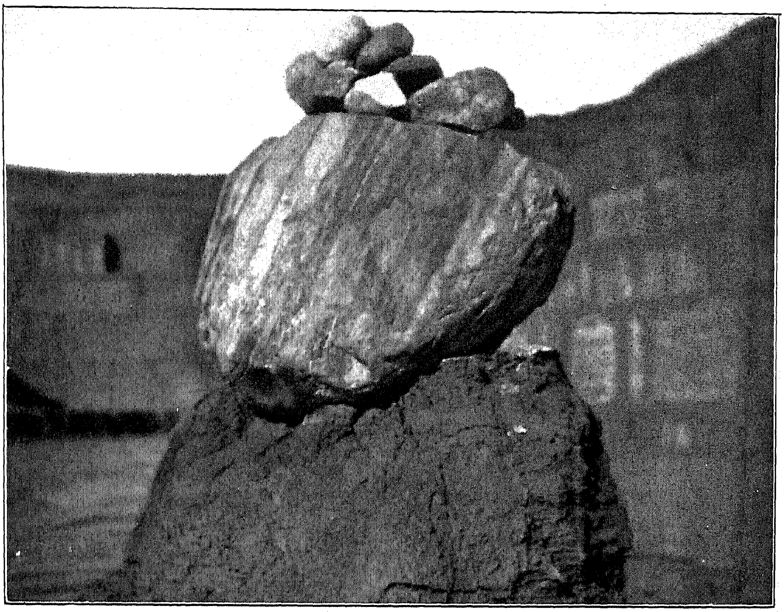
nected at that point. To expedite this procedure, a 3-foot chain is looped, hook and ring, and loosely dropped around the top of the gin. As the pipe is withdrawn from the hole it is so directed at the top as to enter this loop. After withdrawing the six sections as described, the handle is now attached again

FIG. 6.



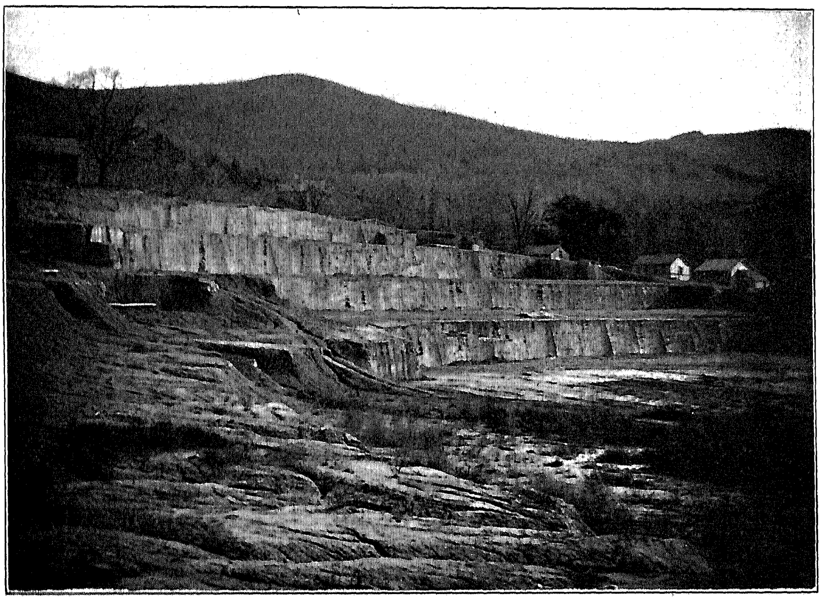
below the lowest coupling (where it already lies in place), the 30-foot length is unscrewed, and being held upright by the loop at the top of the gin, is merely set at one side. The chain on the fall is again attached to the pipe above the handle, a stress applied to the rope, the handle loosened as before; and this process is continued for each 30-foot length until the auger

FIG. 7.



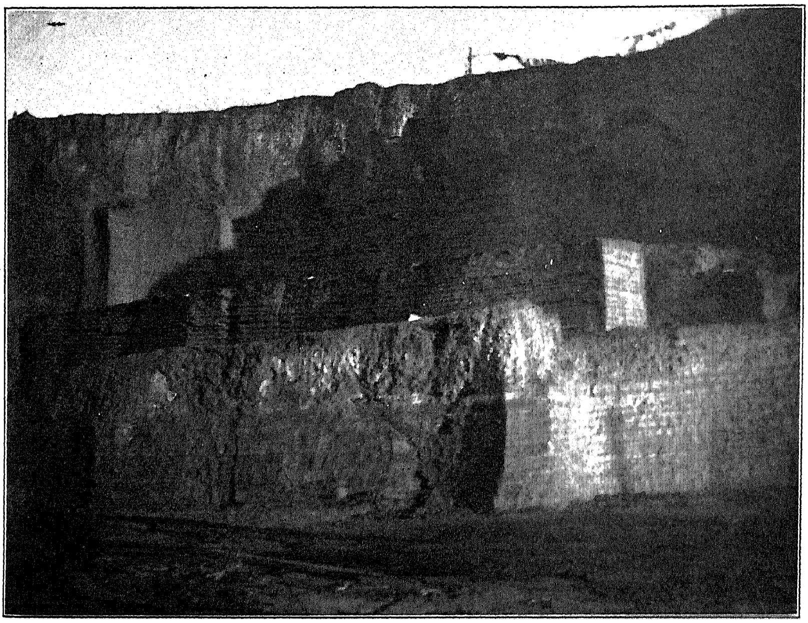
Large Boulder at Jova's Clay-Bank, Roseton.

FIG. 8.



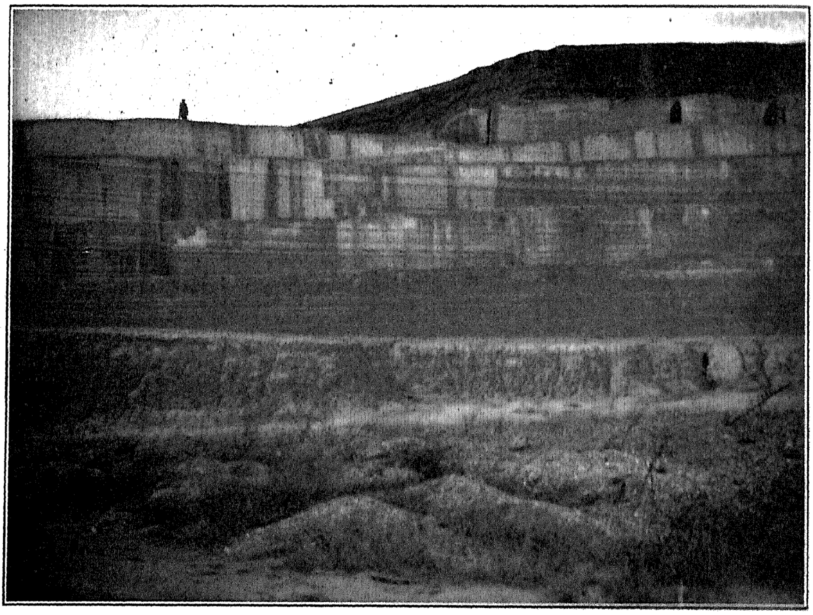
Aldridge's Clay-Bank, Dutchess Junction.

FIG. 9.



Dinan's Clay-Bank, W. S. Verplanck Estate, Fishkill-on-Hudson.

FIG. 10.



Rose's Clay-Bank, Roseton.

has been withdrawn from any depth; the invariable rule being to have always either the handle or the chain under stress below a coupling attached to the pipe, while the auger remains in the hole. This operation is reversed to lower the pipe again into the hole, *i.e.*, the sections are replaced in the order of their removal. It follows that the depth of the hole at any time can be ascertained from the number of sections in use. At depths exceeding 75 feet (frequently less), the chain-block must be used to start the auger, hooking it on to the wooden fall when required. In this manner, with a little training and a proper division of the duties of each man in the gang, the boring becomes practically continuous, and proceeds very rapidly. One hundred feet of pipe can be started, pulled up, disconnected, the auger-bit cleaned, and the whole apparatus let down into the hole again in a few minutes.

When sand is encountered, enough water to make it adhesive must be poured into the hole, and the auger will then carry it to the surface. Thin strata of sand cause difficulty, and, similarly, fine gravel is frequently impenetrable. For holes of this size the various sand-pump devices are failures, and the auger alone will do the work better. The drill, with or without the iron-rod section, offers the readiest solution to the gravel-question. Gravel must be broken up or pushed to one side. The knack of manipulating the drill to meet these circumstances can only be imparted by experience. The best plan is to instruct practically the foreman alone, who must then deal personally with the difficulty when it arises.

Quicksand is another great obstacle to deep boring. If the quantity of water is small, and the stratum thin, it is occasionally possible to penetrate it by very rapid work, and bore to the depth required for a given purpose; but a thick seam is impenetrable by the auger, on account of the closing up of the hole through the vacuum created by withdrawing the auger, or by the pressure of superincumbent masses. Casing will not overcome this difficulty. Ordinarily, and especially in test-boring in clays, it is unnecessary to penetrate quicksands.

A long chapter could not fully treat the subject of accidents. A general rule other than an exhortation to patience is out of the question, because of the variety of these seemingly trifling mishaps. Grappling-devices to remove accidental obstacles in

a bore-hole are all excellent in theory, but the simplest devices often succeed where the more elaborate fail. A section of pipe becoming disconnected in the bore-hole can be caught up by using the disjointed member provided with a clean, freshly-oiled coupling; a coupling can often be removed from a hole by using a taper-pointed stick driven into the end of the pipe; an auger broken at the shank may be grasped by a noose of short-link chain lowered by two strings, which is then grappled by a hook on the end of the ½-inch rod or pipe, or entangled around the small drill. Most of the mishaps happen through neglect of the simple rules given. It is important always to avoid gorging the auger at great depths. It is apt to be frequently clogged at the bottom of a long column of pipe, and it is not advisable to then reverse the auger to release it.

Geologic Description.*

Verplanck's Point.

Verplanck's Point is in the western part of the town of Cortlandt, the extreme northwestern town of Westchester county, N. Y.

It is an irregular ridge of rock, mainly coarsely crystalline, with masses of granular limestone and black shales, both partially metamorphosed, and, according to Prof. J. D. Dana, belonging to the Taconic or Cambro-Silurian system, outcropping at several places near the southern end of the peninsula.

It has its longer axis in a northeast and southwest direction, and its highest peaks are about 125 feet above the level of the Hudson river, by which it is nearly surrounded.

The Point is nearly two miles long by two-thirds of a mile wide, and is very rough, huge masses of bare rock rising above the soil in many places, especially in the higher portions.

There is abundant evidence that the clays, sands and gravels deposited during the great subsidence of the Champlain Epoch in the Hudson river valley, and composing distinctly marked terraces which occur in, with a slightly increasing elevation towards the north, the depressions and openings in the adja-

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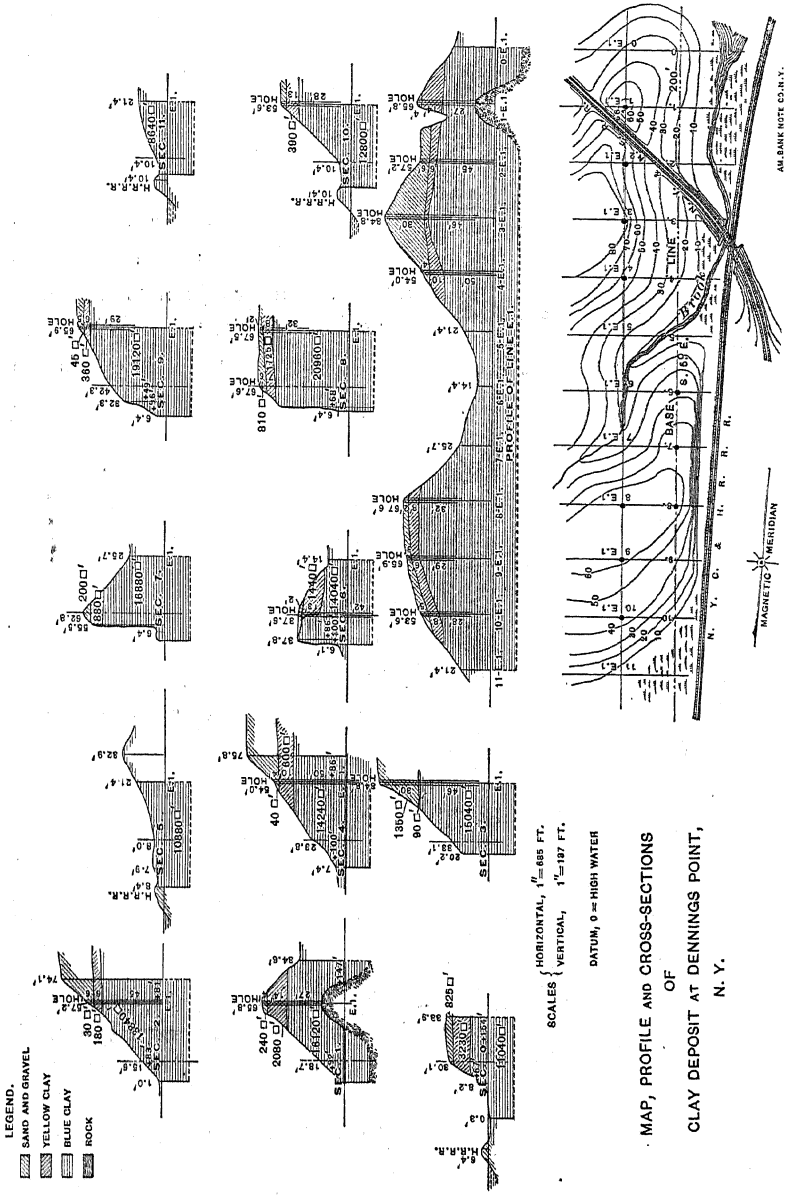
* These geologic notes were prepared by Mr. D. D. Luther, Assistant New York State Geologist.

cent hills and mountains, once covered nearly the whole area of the peninsula.

The terrace-plateau is well-marked in several localities, at

FIG. 11.



MAP, PROFILE AND CROSS-SECTIONS OF CLAY DEPOSIT AT DENNINGS POINT, N. Y.

one of which King's clay-pit has been opened, and a considerable quantity of brick-clay has been removed. This deposit is in a depression on the south side of the central part of the

Point. Where the clay has been removed it was in immediate contact with the underlying rock, which is very uneven, with projecting irregularly-shaped masses more or less rounded, scratched and partially polished by glacial action. This is especially the case on the north side. The striæ have the general direction of the river-channel. In a few instances small pockets of gravel derived from the adjacent rocks were found in the depressions between the hummocks; and occasional boulders also occur.

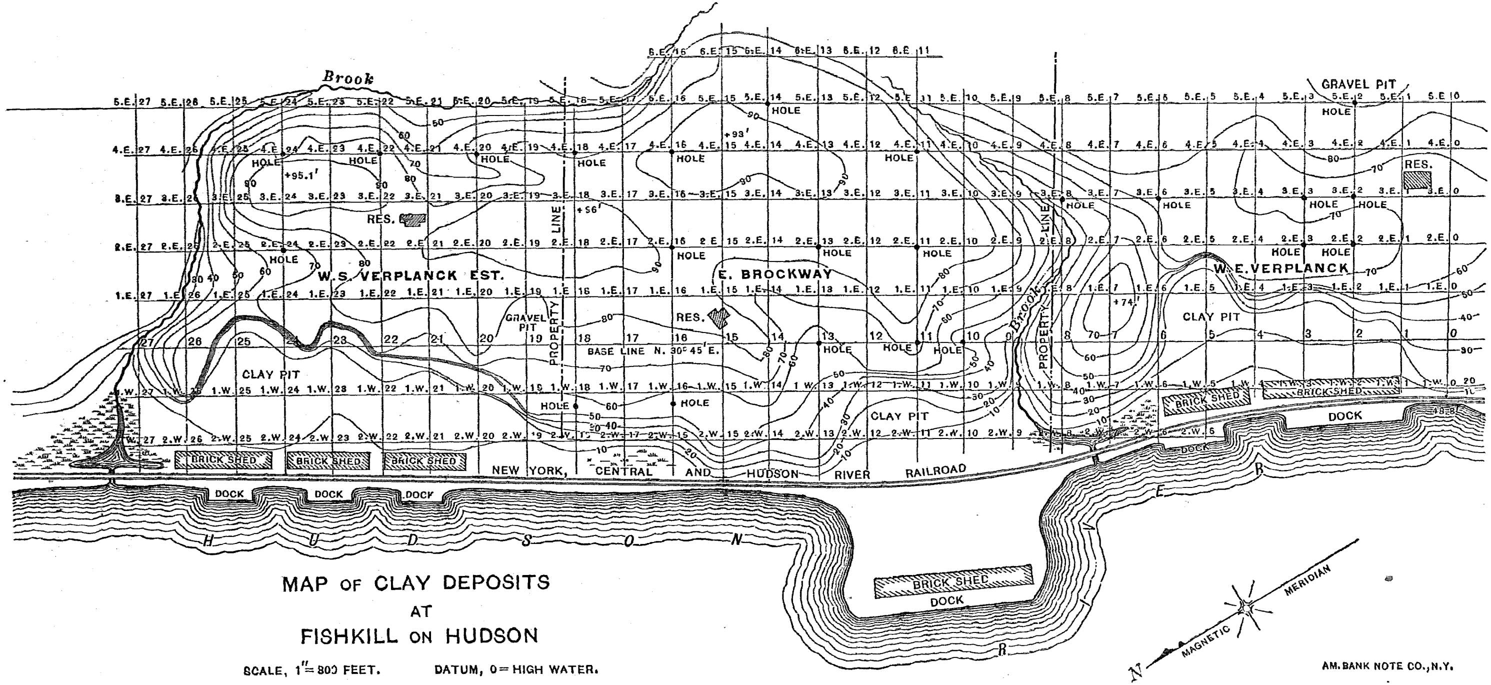
The clay is principally of a bluish lead-color, and quite evenly laminated, showing the lines of deposition very distinctly, owing to the intermixture, in alternate layers, of fine quicksand of somewhat lighter color. These "quicky" layers are more susceptible, when dry, to the action of wind than the tougher layers of purer clay, and, when wet, "run," so that, after a short exposure, an examination of the vertical walls of a pit shows the clay-layers to project more or less, thereby exhibiting the lines of deposition very strikingly.

The blue clay is usually overlain by a stratum of brownish-yellow clay, which varies in thickness from a few inches to 15 or even 20 feet, according to position, being thicker on slopes where the stratification has been disturbed by slides, etc. The contact-line between the yellow and the blue clay is not conformable with the lines of deposition, which usually extend without break from the blue into the yellow, but is approximately parallel to the upper surface of the clay-bed, showing that the difference in color is not due to separate deposition.

The upper surface of the clay-bed, as it appears in the sections exposed in the pits, is uneven, and not conformable with the bedding-planes of the deposit. It exhibits every evidence of having suffered much erosion before the superincumbent sands and gravels were spread over it; and it plainly appears at many exposures here and at other localities that only a part of the original deposit of clay was covered and preserved in the terraces and deltas that are now to be seen along the sides of the Hudson River valley, the other and far greater portion having been previously swept away.

Overlying the yellow clay is an irregular and uneven deposit of coarse and fine gravel and sand, with occasional small, irregular beds of loam and yellow clay. The surface-soil is generally

FIG. 12.



MAP OF CLAY DEPOSITS
AT
FISHKILL ON HUDSON
SCALE, 1″= 800 FEET.
DATUM, 0 = HIGH WATER.
Brook
GRAVEL PIT
W. S. VERPLANCK EST.
E. BROCKWAY
W. E. VERPLANCK
CLAY PIT
GRAVEL PIT
PROPERTY LINE
BASE LINE N. 30° 45′ E.
RES.
HOLE
+95.1′
+93′
+56′
+74′
BRICK SHED
DOCK
NEW YORK, CENTRAL AND HUDSON RIVER RAILROAD
HUDSON RIVER
MAGNETIC
MERIDIAN
N
AM. BANK NOTE CO., N.Y.

loamy and sandy. The thickness of this deposit is very uneven, varying from 8 to 20 feet. Horizontal lines of deposition rarely occur, and cross-bedding is common.

The gravels are sometimes composed of small, well-rounded pebbles of quite uniform size, and sometimes of angular fragments of the adjacent crystalline rocks, of all sizes. More or less sand is intermingled with them.

The base-line of this survey, on which holes No. 1 to No. 15, inclusive, were sunk, extended from a point near the center of the vertical wall or face of the north side of King's pit, in a northerly direction over the low "col" that separates this depression from one on the west side of the Point, in which occurs the deposit of sand owned and utilized by the Bonner Brick Company. Clay formerly occurred in this depression also, but the bed has been practically exhausted for the manufacture of bricks.

Line A E was parallel to the base-line, and 200 feet east of it.

Line A W was 200 feet west of, and also parallel to the base-line.

No clay was found in any of the borings except in No. 2, where 2 feet 1 inch was found next to the rock.

In the other holes gravel and sand were penetrated, pebbles and small boulders occurring occasionally.

All of the holes were sunk to what appeared to be solid rock.

On the north side of the Point a clay-pit has been opened by the Bonner Brick Company in a depression of rather small area, which is drained through a small ravine at the west end, opening into the western lobe of Lent's cove.

It is sheltered on the north by a rocky ridge from 40 to 50 feet higher than the enclosed plain. The material deposited in this basin is of the same general character and in very much the same condition as at King's pit, and it has also been nearly exhausted of good brick-clay.

Some good material doubtless yet remains on the south and west sides of the main pit, but it is covered by several feet of coarse gravel, containing boulders of considerable size.

Several small deposits on the east side of Lent's cove for-

merly furnished good brick-clay, but appear to have been nearly or quite exhausted.

Dutchess Junction.

The [illegible] at this locality constitute the principal part of the broad and well-defined terrace which extends along the sides of the Newburgh bay trough, at the foot of the Fishkill and the Breakneck mountains. This trough crosses the Hudson river valley diagonally, in a northeast and southwest direction, having on its southeastern boundary the steep slopes and high peaks of *Archean?* granites, diorites, gneisses and schists comprising the Highlands, and on its northern and western borders, at a somewhat less elevation, rugged cliffs and high escarpments of upturned and partially metamorphosed Hudson River shales and Cambro-Silurian limestones.

In this great trough the Champlain terrace is well defined at many places, and the high benches, with their flat upper surfaces and steep sides sloping towards the river, are striking features in the landscape.

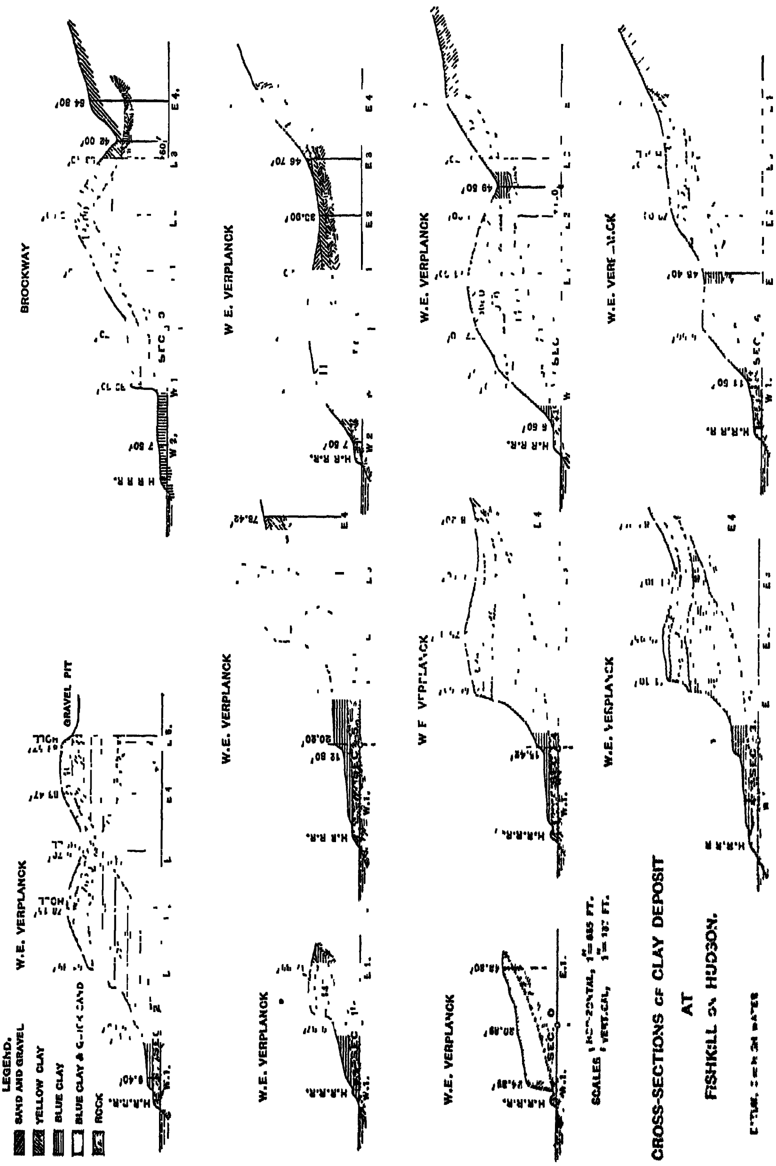
At Dutchess Junction the terrace is strongly defined, and extends from near Fishkill creek on the north to Cascade brook on the south, a distance of more than a mile. Several small ravines have been cut in it at the north end by small streams that empty into Fishkill creek. Near the south end, Melgingah brook has excavated a wide gorge down to bed-rock, and almost to the level of the river; and the ravine of Cascade brook, nearly as large, separates the south end of the terrace from a rocky ridge that extends to the river.

The clay-bed here is coextensive with the terrace and very thick, and presents precisely the same appearance and characteristics as the bed at Verplanck's Point, except in regard to quantity. At the north end, in the vicinity of Fishkill creek, and on the south side, next to the mountain, the clay is underlain in some places by what seems to be a morainic mass of clay, gravel and boulders. Some of the boulders are very large, and many of them show glacial scratches and polishings.

In the main portion of the bed the clay was found in immediate contact with the underlying rock, there being only a slight admixture of fine dark sand and small particles of gravel at the bottom of the holes.

The boulders and gravel found in the clay are generally more or less angular in shape, and were largely derived from the Cambro-Silurian limestones and Hudson River shales, which

FIG. 13.



are exposed in the bed of Fishkill creek, about a mile to the northeast.

The beds overlying the clay are heterogeneous in character, the materials ranging from large boulders to small pockets of

fine clay, all without any systematic arrangement, but irregularly bedded, [illegible] strongly the features of flood plain- and delta-deposits. The principal part of the material composing the upper gravels and sands was contributed by the adjacent crystalline rocks, but they contain also many angular or rounded fragments of limestone and flattened grains of red, black or gray Hudson River shales, together with pebbles and boulders of the same rocks.

Above the terrace-level, and lying against the face of the mountain, a series of low foot-hills of varying sizes and shapes are composed of gravel and sand irregularly deposited, derived almost wholly from the Fishkill pits.

Near the Gurnee clay-pit, on the north side of the ravine of Melgingah brook, and about midway between the foot of the mountain and the river, a large mass of crystalline rock is exposed. It is the south end of a ridge almost buried in clay, sand and gravel, which lies nearly parallel to the mountain. In several places towards the north, near the residence of Mr. T. Aldridge, it projects above the terrace-level in the shape of low oblong hummocks, rounded and polished by glacial action. This ridge of rock divides the Dutchess Junction clay-deposit, as it now exists, into two parts, though that deposit was beyond doubt formerly continuous and much more extensive along the river front.

The heavy beds of gravel and sand that overlie the clay on the south side of the ridge appear to be the delta-gravels of Melgingah and Cascade brooks.

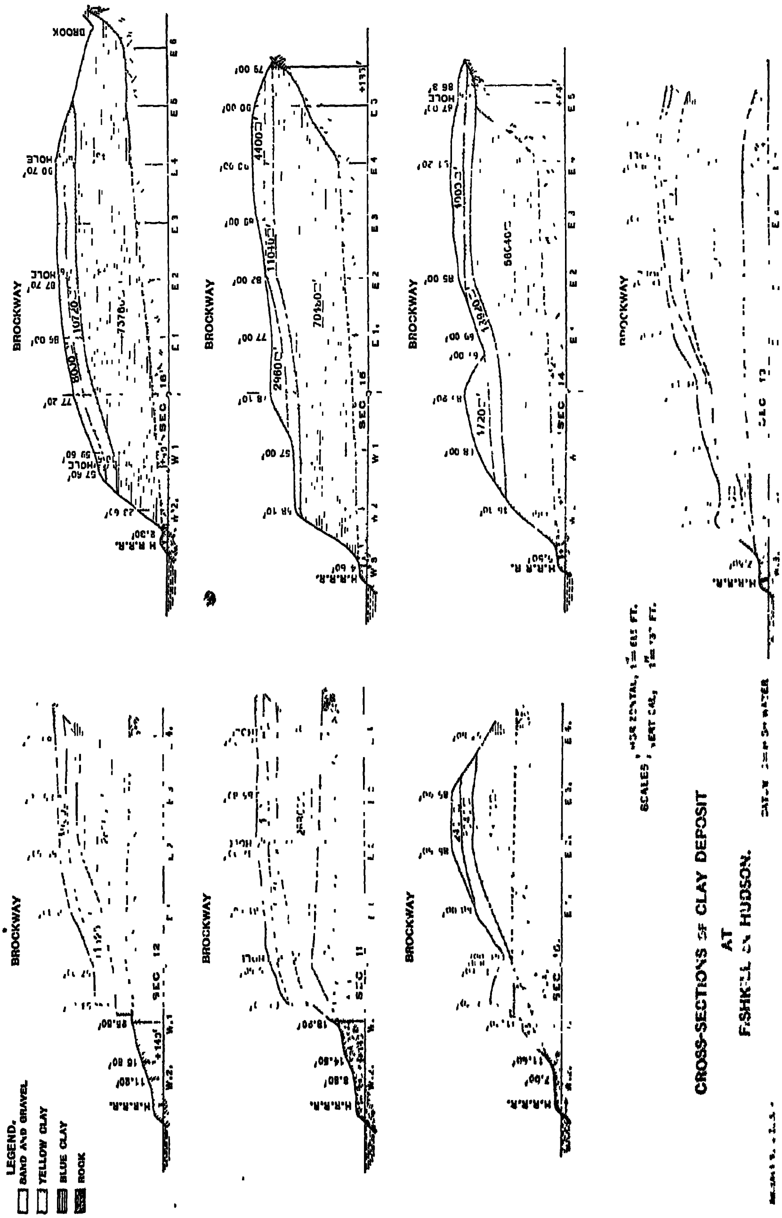
Denning's Point.

The clay-bed at Denning's Point is on the north side of Fishkill creek and on the mainland immediately in the rear of the Point—a low sandy peninsula, terminating in a ledge of rocks which rises but a few feet above the river level. The clay is a part of the same deposit as that of Dutchess Junction, now disconnected by the action of the waters of Fishkill creek. Being near the creek and lacking the shelter of the mountain-ranges, the bed has suffered much erosion, and is very irregular in shape.

The overlying gravels are rather fine-grained, with much coarse sand intermixed with them, and, on the flat surface of

the terrace, of unusual thickness. Thirty feet of loam, sand and gravel covered the clay at Boring No. 3, E 1.

FIG. 14.



About ½ mile east of the bed, near the hat-factory, upturned Hudson River shales are exposed in the channel of Fishkill

creek, and the underlying rock of the clay-bed is probably of that formation.

Fishkill-on-Hudson.

The clay-bed at this locality extends nearly 6000 feet along the river, northward from a small ravine on the north side of a bluff of upturned Hudson River shales, that overhangs the river about one mile north of the foot of Main street in the village of Fishkill Landing. It is bounded on the north by a small ravine and creek opening into the river. In the bottom and on the side of this ravine several exposures of Hudson River shales occur.

The deposit extends back from the river for an average of about one-third of a mile to a nearly buried ridge of rock, the position of which is shown by a line of outcrops in the shape of low rounded knolls of black shales standing on edge, partly metamorphosed, and scratched or roughly polished by glacial action. These shales belong to the Hudson river group.

Borings showed this ridge to be continuous, since, at all points along its axis, which is parallel to the strike of the strata, rock was found near the surface. Near the south end of the terrace the ridge is somewhat lower, and some blue clay was found on the east side of it.

The clay-bed is of the same character as at Dutchess Junction and Verplanck's, except that boulders of limestone and black shale, and more rarely of crystalline rocks, are quite common, and in one locality of small area these boulders, large and small, with some intermingled gravel distributed through the clay, formed, at about 25 feet from the top, so large a proportion of the deposit as to impair seriously, if not to destroy, its value for brick-making.

The lines of deposition show a strong dip towards the river, and some of the "quicky" layers are crumpled. The overlying deposit is quite fine and very evenly grained, and contains a large proportion of excellent tempering-sand. Some small portions of the gravel are cemented by yellow clay into tough irregular beds of what is locally known as "hard-pan."

Roseton.

The principal clay-bed at Roseton, the one from which the Rose Brick Company and the Jova Brick Company obtain the

material for their large output of bricks, underlies the broad terrace-plateau which fronts the river on the north side of the small brook flowing eastward into the Hudson at this place. The terrace is bounded on the south by a deep and wide ravine, through which this brook flows, and on the north and west by a line of jagged cliffs and escarpments of dolomitic limestone of the same character and age, apparently, as that which appears at Verplanck's Point. It occurs as a high bluff at Hampton Point, 1.5 mile north. On the north side of the terrace, an opening, through which the West Shore Railroad runs, separates a rocky ridge, formerly an island, the northern extremity of which is known as Danskammer Point and which extends almost to the clay-beds, from the outcropping ledges of rock limiting the terrace on the northwest. On the southern bank of the ravine, on the south side of the terrace, the folded and upturned rock-strata rise at a steep angle to the height of from 250 to 300 feet above the river, with many exposures; and the whole country in the vicinity is exceedingly rough and rocky—jagged ridges and vertical escarpments, enclosing small irregularly-shaped valleys, which are sometimes isolated and sometimes connected by narrow openings.

The principal clay-deposit occupies the whole (except the space included between the banks of the ravine previously mentioned) of a deep depression, open towards the river, about half a mile long and nearly as broad. The clay is very thick, beautifully laminated, and presents the same characteristics as the other beds already described. Boulders are rare, only one large one being observed. This, as shown in Fig. 7, had evidently been allowed to remain *in situ*, supported on a column of clay carved out as the excavation proceeded around and below it.

The proportion of quicksand is quite large, especially below the level of the river. The overlying gravels are from 12 to 20 feet thick, and irregularly bedded. The pebbles are well-rounded and of very uniform size, mainly between ¼ inch and 1 inch in diameter. The gravel is coarser on the south side, next to the ravine, and a layer of coarse conglomerate or "hard-pan," of uneven thickness and considerable extent, has been formed through the cementation of the gravel by calcic carbonate deposited from percolating waters. On the side next

to the river extensive slips have occurred, and the bedding lines show foldings, crumplings and faultings in a striking manner.

Rose Farm.

The excavation effected by the ravine on the south side of the main terrace cut off a small irregular lobe, formed by the filling of a shallow depression west of the north end of the principal depression. This basin, which is of irregular shape and nearly surrounded by outcropping ledges of rock, was found to have a rock-bottom as uneven as its outline, and to contain a considerable deposit of sand next to the floor and another at the top, with an irregular bed of blue clay intercalated between them. The surface of this tract, known as the "Rose Farm," has been unevenly eroded, but that it is a part of the original terrace-plateau is plainly evident.

Armstrong.

About a mile north of Roseton, and separated from the Danskammer ridge by a narrow cut through which the West Shore Railroad runs, a part of the D. M. Armstrong farm contains another lobe of the terrace-plateau. The plateau is triangular in shape, with a steep slope on the river-side, and is bounded on the south by a deep ravine that extends easterly along the northern foot of the rocky ridge, previously mentioned as forming the northern boundary of the main terrace at Roseton. On the northwest side another ridge of limestones, high and exceedingly rough, extends northeast to the river. The Armstrong terrace is thus entirely surrounded, except on the river side, by ridges of rock higher than the terrace-level.

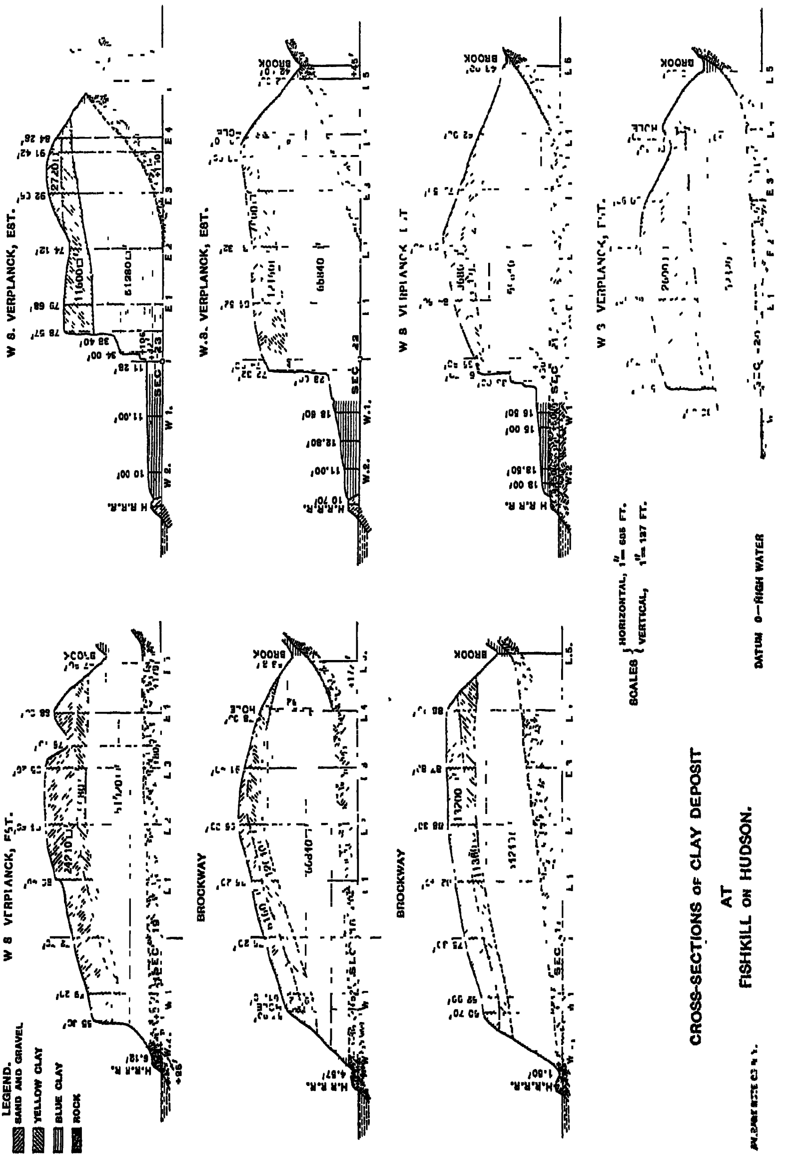
The character of the material deposited in the basin is much the same as at other localities described, except that the lower bed, next to the rock, is composed of fine yellowish gray sand, and is of greater thickness. The upper bed is also largely a sand-bed, with fine rounded gravel near the surface at the south end, and some coarser drift-gravels, with boulders, at the extreme north end.

Between these two sandy and gravelly beds lies an uneven bed of excellent blue clay, in which the proportion of quicksand appears to be small.

On the south side of Roseton creek some remains of the ter-

race are still to be seen, but the character of the deposit is very different from that on the north side. Hardly any trace of stratified clay appears, except near the south end of the de-

Fig. 15.



posit, where a small amount of yellow clay, interstratified with fine sand and loam, occurs. Nearly all of the material is fine to coarse sand and gravel, with abundant large and small boulders of limestone.

There is doubtless a very large quantity of good sand yet contained in these beds, though a large amount has been removed. In one pit about 65 feet of sand is exposed.

The sand-bed is south of a ridge of rock that outcrops near the railroad, a few rods north of the station.

ECONOMIC DESCRIPTION.

The localities investigated are considered in the order of progress up the river. The entire contents have been tabulated for each locality; and, wherever possible, the three principal materials, blue clay, yellow clay and sand, have been separately computed.

Localities.

For the sake of reference, the brick-producing localities of the Hudson river valley are here divided into districts. These are numbered as follows: 1, Croton Point; 2, Haverstraw; 3, Stony Point and Grassy Point; 4, Verplanck's Point, Cruger's, Montrose and Peekskill; 5, New Windsor and Cornwall-on-Hudson; 6, Dutchess Junction and Denning's Point; 7, Fishkill-on-Hudson and Fishkill Landing; 8, Roseton.

Weights Used in Computation.—The average size of the Hudson river bricks is hard to determine. They vary from $2\frac{3}{16}$ by $3\frac{7}{16}$ by $7\frac{7}{8}$ inches to $2\frac{1}{2}$ by $3\frac{1}{2}$ by 8 to $8\frac{3}{16}$ inches.

The average weight is taken at 4.5 pounds (a high estimate). The amount of water expelled in burning is about 0.9 pound or 20 per cent., making the weight of the green brick 5.4 pounds. One thousand green bricks will therefore weigh 5400 pounds or 2.4 long tons. One cubic yard of clay in its average natural state will weigh 3240 pounds. One thousand green bricks will therefore occupy 1.66 cubic yards. But the average mixture of sand used is 25 per cent., which, with the water, is equivalent to 0.46 cubic yard, leaving the amount of clay required for 1000 bricks 1.20 cubic yards. Deducting the amount of water added in manufacture, the average amount of sand required per thousand of bricks for mixture is 0.40 cubic yard.

Districts 1, 2 *and* 3.—Croton Point, Haverstraw, Stony Point and Grassy Point were not surveyed or tested. At neither of these localities was there sufficient material in sight (a matter clearly determinable by the exposure of clay in the pits) to

warrant a general examination. Assuming the former terrace-heights on the river-front to have been 100 feet above mean tide-level, and taking the average depth of the present excavations at about 40 feet below mean tide-level, it is apparent that a maximum thickness on the river-front of about 140 feet of clay has been removed. Since the maximum thickness of clay determined by this survey, later on, was but 152 feet on the river-front, at a point where the terrace-level is at least 15 feet higher, the opinion appears to be fully confirmed that the ultimate commercial depth has been reached in these localities, and that except in a few instances the deposits are now practically exhausted. It should be remarked, in addition, that a characteristic of these clay-deposits, first revealed by this survey, and shown consistently by all the cross-sections, is the tendency of the underlying rock, at least at the terrace-locations, to rise to the surface, often abruptly, as its distance from the river-bank increases. A review of the rock-horizons under such conditions makes it evident that, at the present rate of consumption, the clay-deposits of these localities can last but a few years.

District 4.—The deposits at Cruger's, Montrose and Peekskill are small pockets, partially or completely worked out. Verplanck's Point offered the first suitable opportunity for testing. Here the terrace-level suggested as probable a persistent depth and extension of the clay-deposit. This fact, in connection with the contiguity of the district to Nos. 1, 2 and 3, which had been so largely productive in the past, led to tests which gave as a result the estimate of 26,730 cubic yards of clay, equivalent to 22,300,000 bricks. There are several other small deposits scattered over the peninsula, but, by reason of the comparatively small quantity discovered in the tract investigated, these were not tested.

Maps and cross-sections of this locality were omitted, as the quantity of clay was found to be comparatively insignificant. The value of thorough testing was strikingly demonstrated here. The definitely unknown territory gave surface-indications of a large deposit. Moreover, large clay-pits were being worked at both ends of the base-line, and the owners of the intervening property considered the deposit to be continuous through that ground. The tests developed the fact that the

pits were being worked in pockets, between which lay a barren ridge of rock—or "hog-back"—obscured by a covering of sand and gravel, from a few inches to 30 feet thick.

District 5.—New Windsor and Cornwall-on-Hudson were not tested, since all the indications pointed to small irregular pockets. At both of these localities, however, there are large quantities of sand; in fact, the deposits of sand predominate.

District 6, *Dutchess Junction.*—The tests of the Gurnee, Aldridge and Timoney tracts, at Dutchess Junction, gave the following results:

	Sand and gravel. Cubic yards.	Yellow clay. Cubic yards.	Blue clay. Cubic yards.	Total clay. Cubic yards.
Gurnee, . .	92,092	144,685	1,305,878	1,450,563
Aldridge, . .	894,148	457,554	12,270,452	12,728,006
	986,240	602,239	13,576,330	14,178,569
Timoney tract, .	259,185	23,547	1,370,740	1,394,287
Total for Dutchess Junction,	.	.	. . .	15,572,856

	Sand. Feet. Av. thickness.	Yellow clay. Feet. Av. thickness.	Blue clay. Feet. Av. thickness.
Gurnee, Aldridge, ...	4.32	2.64	59.55
Timoney tract, . . .	6.1	.55	32.3

The total area of the Gurnee bed is 141.3 acres; that of the Timoney tract is 26.3 acres; the Aldridge shows a continuous length of face of 4700 feet. The Timoney tract shows 600 feet of working-face, making a total of 5300 feet.

The 15,572,856 cubic yards of clay estimated as available in the Dutchess Junction district is equivalent to 12,977,380,000 bricks. The total amount of sand required for this number of bricks would be 5,190,952 cubic yards, and the total amount of sand surveyed was 1,245,425 cubic yards, giving a deficiency of 3,945,527 cubic yards of sand. Figs. 1 to 6, inclusive, give maps and sections of these deposits, and Fig. 8 is a view of the Aldridge bank.

District 6, *Denning's Point.*—Tests of this deposit showed:

Sand and gravel. Cubic yards.	Yellow clay. Cubic yards.	Blue clay. Cubic yards.	Total clay. Cubic yards.
28,000	71,074	1,285,925	1,356,999
	Average thickness.		
1.2 feet.	3.2 feet.	59 feet.	

The 1,356,000 cubic yards of clay in this deposit are equivalent to 1,130,832,000 bricks. The length of the base-line was 2279 feet 6 inches. The amount of sand required for the

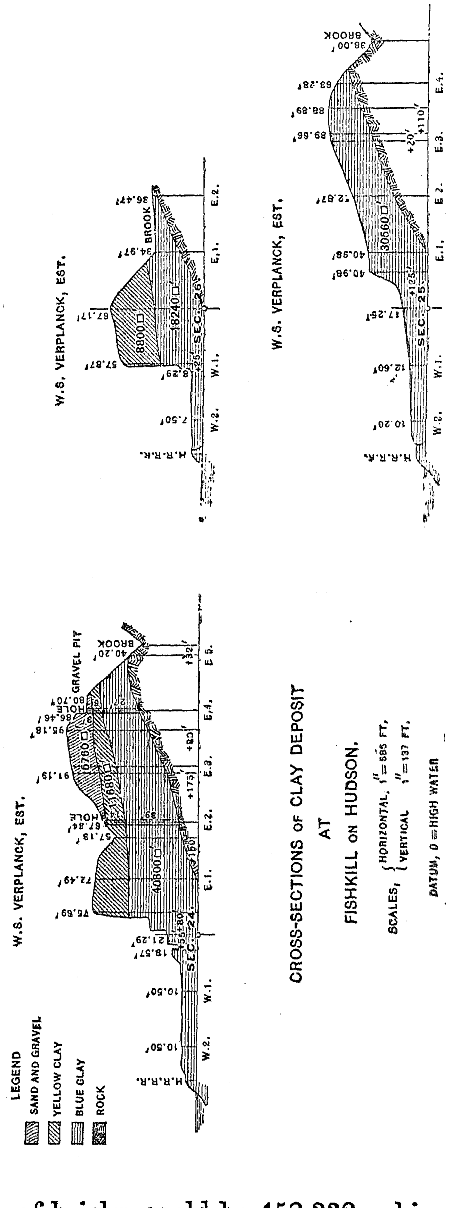


FIG. 16.

stated quantity of bricks would be 452,332 cubic yards, and the amount surveyed was 28,000 cubic yards, showing a deficiency of 424,332 cubic yards.

Fig. 11 shows map and sections of the deposit at Denning's Point. The total amount of clay at Dutchess Junction and Denning's Point is 16,929,855 cubic yards, equivalent to 14,108,212,000 bricks.

It should be understood that all areas stated refer to the clay-deposits only, and not to property-lines.

District 7.—The tests at Fishkill-on-Hudson showed:

	Sand and gravel. Cubic yards.	Yellow clay. Cubic yards.	Blue clay. Cubic yards.	Total clay. Cubic yards.
W. S. Verplanck, .	308,220	304,740	814,814	1,119,555
Brockway, . .	530,370	818,370	3,381,925	4,200,296
E. Verplanck, .	562,962	477,629	2,746,666	3,224,296
	1,401,552	1,600,739	6,943,405	8,544,147

Average thickness of gravel, 0.21 feet; of clay, 33.8 feet; total area, 156.3 acres; length of continuous working-face, 5300 feet. The 8,544,147 cubic yards of clay estimated are equivalent to 7,120,120,000 bricks, for which the total amount of sand required would be 2,848,048 cubic yards. The amount of sand surveyed was 1,401,552 cubic yards, showing a deficiency in sand of 1,446,496 cubic yards. Fig. 9 is a view of Dinan's clay-bank on the W. S. Verplanck estate; and Figs. 12 to 16 inclusive give map and sections of the locality.

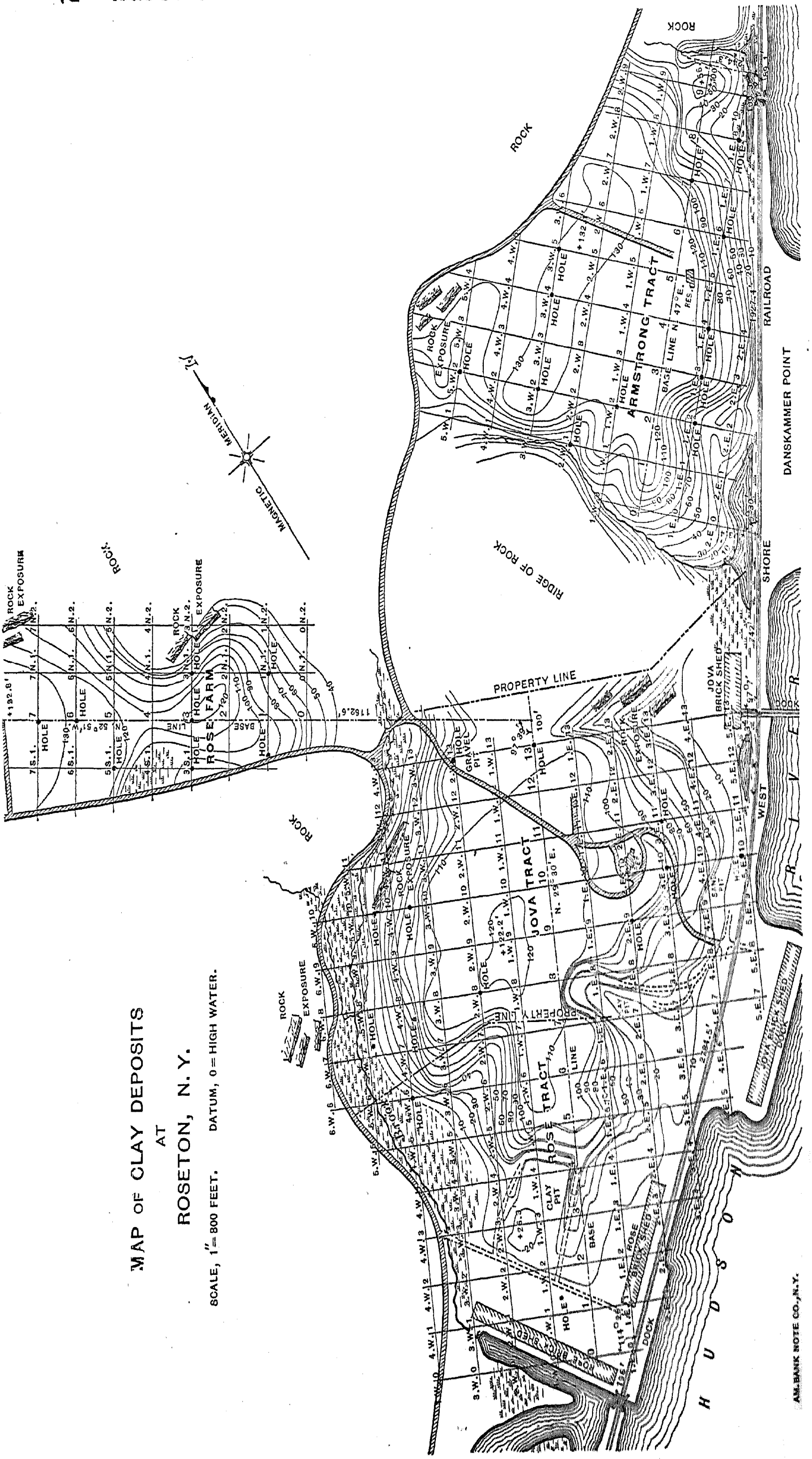
District 8.—Tests at Roseton gave the following results:

	Sand and gravel. Cubic yards.	Yellow clay. Cubic yards.	Blue clay. Cubic yards.	Total clay. Cubic yards.
Rose, . . .	281,481	3,333	3,102,814	3,106,147
Rose Farm, .	321,777	127,407	290,963	418,370
	603,258	130,740	3,393,777	3,524,517
Jova, .	1,534,222	459,852	4,433,777	4,893,629
Armstrong, .	2,347,852	238,222	867,555	1,105,777
	4,485,332	828,814	8,695,109	9,523,923

Average thickness.	Feet.	Feet.	Feet.	Area, acres.
Rose and Jova, ...	13.9	3.5	57.5	81.2
Rose Farm, ...	11.8	4.5	10.47	50.
Armstrong, ...	27.7	2.8	10.2	52.4

The 9,523,923 cubic yards of clay here determined would be equivalent to 7,936,600,000 bricks. The total amount of sand required would be 3,174,640 cubic yards, and the amount

FIG. 17.


MAP OF CLAY DEPOSITS
AT
ROSETON, N. Y.
SCALE, 1″=800 FEET. DATUM, 0=HIGH WATER.
ROSE FARM
ROSE TRACT
JOVA TRACT
ARMSTRONG TRACT
RIDGE OF ROCK
ROCK EXPOSURE
PROPERTY LINE
BASE LINE
JOVA BRICK SHED
ROSE BRICK SHED
DANSKAMMER POINT
WEST SHORE RAILROAD
HUDSON RIVER
MAGNETIC MERIDIAN
AM. BANK NOTE CO., N.Y.

determined by survey was 4,485,332 cubic yards, showing an excess of sand of 1,310,692 cubic yards. Fig. 10 shows Rose's bank; and Figs. 17 to 21 inclusive give map and sections of the Roseton deposits.

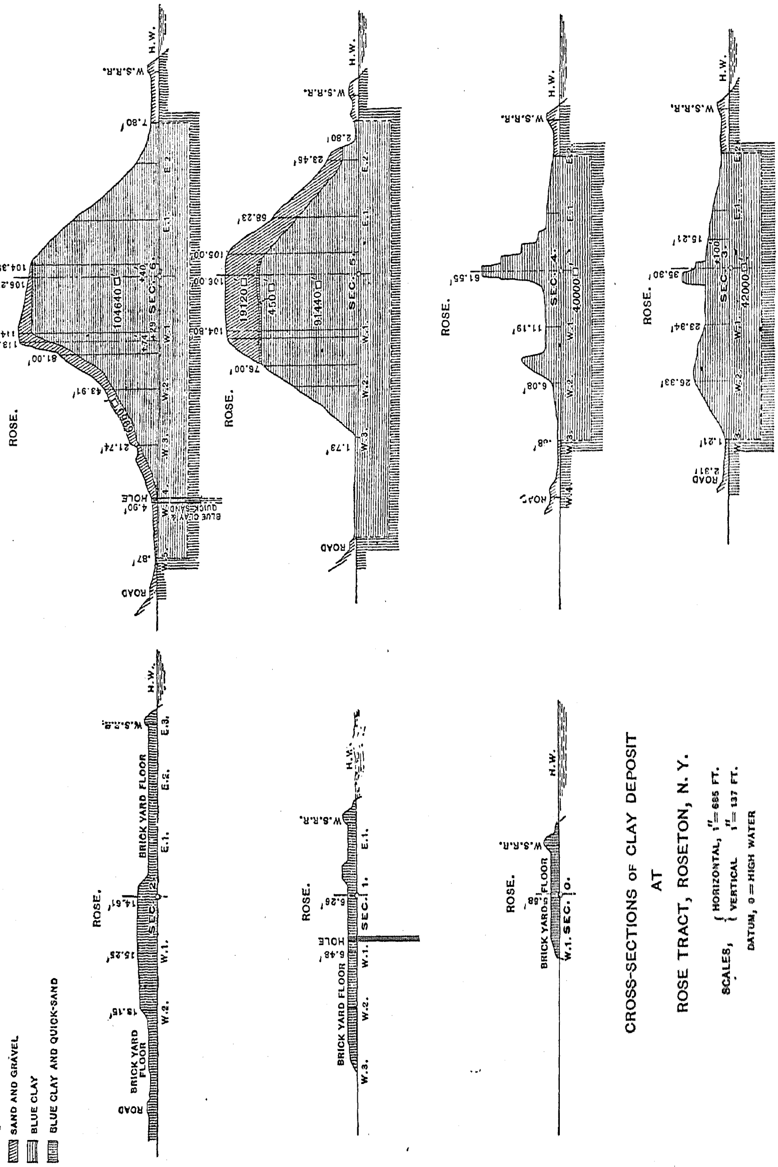
Competition with Hudson River Districts.

Of the States which, under the stimulus of better prices, might compete with the Hudson River districts, Connecticut, Massachusetts, Pennsylvania and New Jersey are the only probable competitors. In 1896 Connecticut produced 166,995,000 common bricks, at an average price of $5.79 per thousand. The same year Massachusetts produced 274,956,000, at an average price of $5.82. Both of these States import common bricks from the Hudson River districts. It is therefore apparent that on the basis either of quantity of production or of the prices received at home, both these States are out of the question. Pennsylvania, which has a formidable production, is unable to cross New Jersey at a lower rate than $1.85 per thousand, within free-lighterage distance only. The production of New Jersey in 1883 was as follows: Hackensack River district, 31,500,000 bricks; Raritan and South River district, 84,000,000 bricks; Raritan Bay and Matawan district, 18,000,000 bricks. The production of the entire State was 186,400,000 bricks. In 1894 New Jersey produced 317,260,000 bricks, at an average price of $5.05; in 1895 248,831,000, at an average price of $4.40; and in 1896 237,781,000, at the low price of $3.99.

While, as a commercial possibility, New Jersey cannot, under competition, produce more than one-third of the annual demand of New York, it is probable that, with the exhaustion of the lower Hudson River districts, as far up the river as Peekskill, and the higher prices which will unquestionably follow, the New Jersey tide-water deposits, at least, will endeavor to contribute a quota to the New York demand. But that quota, outside of the question of the supply of raw material or its duration, can hardly reach 100,000,000 bricks per annum, because the interior demand of New Jersey will not permit a larger exportation. Apart from this consideration, the majority of common bricks produced in New Jersey are not produced at tide-water.

The New Jersey clays differ geologically from the Hudson river clays, and, generally speaking, those which are not of lacustrine origin lack homogeneity. In this latter respect they

FIG. 18.



are not as well adapted for the manufacture of common bricks, owing to the increasing cost of mining layers of different clays. In a face 50 feet in height (which is more than the average

height of the New Jersey clay-banks), from seven to twelve different varieties of clay are frequently encountered. It will be readily understood that this circumstance constitutes a serious commercial handicap in competition with the Hudson river banks, where the stratified clays are homogeneous for a height above tide-water of over 100 feet.

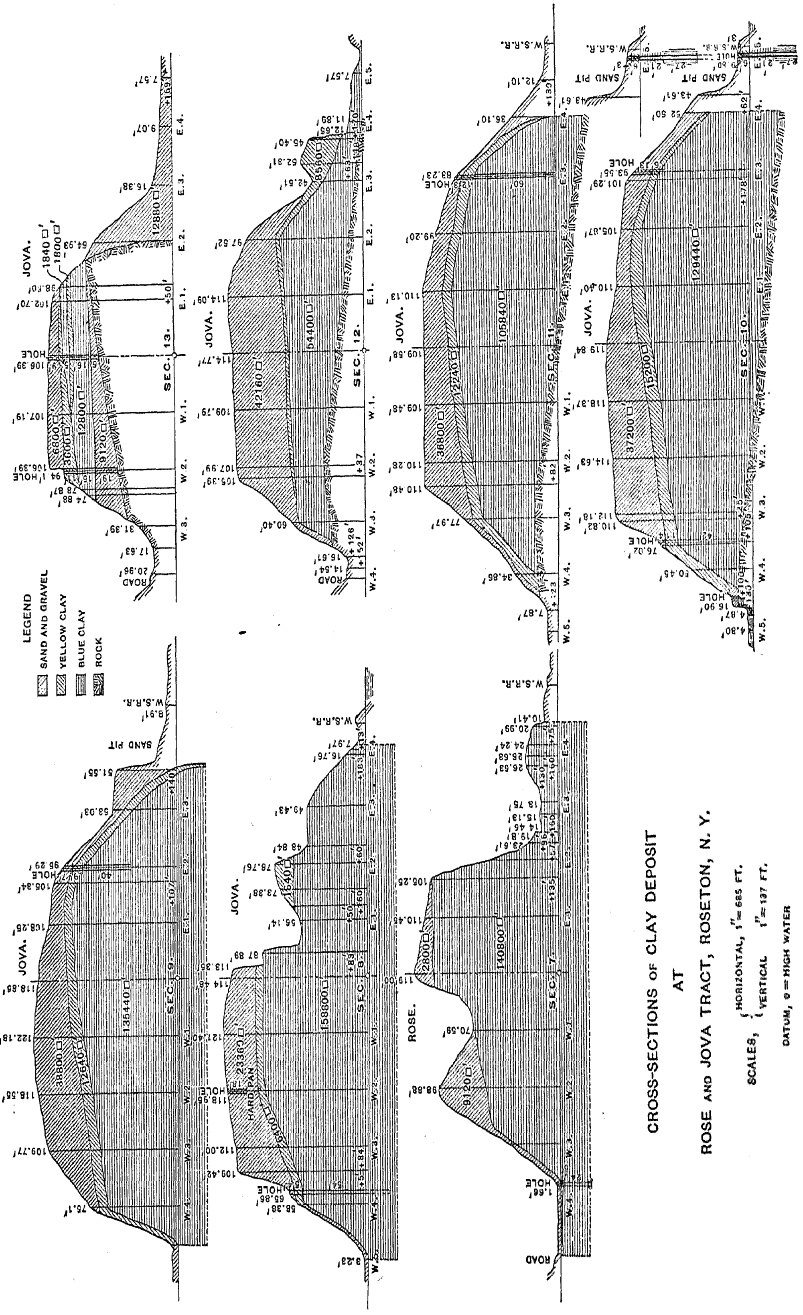
In a smaller degree the Long Island clay-deposits bear about the same commercial and general relations to those of the Hudson river, with the difference that the production of this region will largely enter New York, as it always has done. As disturbing factors in the New York market, neither New Jersey nor Long Island will be distinguishable until after the depletion of the Hudson river valley.

The utilization of materials other than clays for making common bricks is not compatible with prevailing conditions, nor is there discernible prospect of its accomplishment. Certain shales are capable of being made into common bricks; but, as the shales must first be mined and then crushed and reduced, the cost is prohibitory.

Eventually, shales must replace clays in the manufacture of common bricks, but not until the depletion of the clays. The shales that have been used so far in the manufacture of bricks have been the Salina, Chemung, and Hamilton. It is held that the Niagara shales may also be utilized. But the bricks made from shales are in no sense of the word common building-bricks. They are semi-vitrified, so-called paving-bricks, and cost more than twice as much as clay-bricks. Besides, the experimental equation for each and every shale heretofore untried on a commercial scale, is a large and unknown quantity.

Before the use of shales, another possible source of supply would be the recovery of clays washed down in the waters of the river. Dredging for clay is now resorted to at Croton Point: it was also practiced at Haverstraw, but abandoned. If extensive soundings and tests proved the existence of large clay-beds at the bottom of the river, dredging would naturally ensue after the exhaustion of deposits above mean tide-level. But it is questionable in the extreme whether a deposit of any great size exists at all, while the precarious mode of extracting the clay, combined with other disadvantages which preclude its immediate use, renders this phase of the question so problematical that for present consideration it may be dismissed.

FIG. 19.



Between New York City and Danskammer Point, a distance of 65 miles, there are no shales capable of being thus utilized. The character and extent of the Hudson river clay-

deposits, as determined by thorough investigation, establish a commercial duration for them proportionate to their producing power. Natural protection is afforded by the topography of the country through which the valley passes, the mountain-ranges and foot-hills of which shut off outside competition. This is particularly true of the extent of valley between New York City and Danskammer Point, about 2 miles above Roseton, a territory which is here considered as an independent producing-district. Assuming an industrial limit of 3 miles from the river-front as the only admissible range of competitive territory, it will be seen at a glance that the mountains flanking the river on each side form a natural barrier to competition, even should clay-deposits exist beyond them, within the three-mile limit—which is not the case. The natural boundaries they suggest establish a territorial limit at Danskammer Point for a given production, with respect not only to the whole remainder of the Hudson river valley, but also to any other outside competitive territory.

This proposition could be established by a consideration of the freight-rates alone, which define this territorial limit not only for the Hudson river valley, but for any outside producing region. Current freight-rates by water on the Hudson river, from Haverstraw to Roseton inclusive, are $1 per thousand bricks to New York harbor. From Rondout to Coeymans, inclusive, the rates are $1.25 per thousand to New York harbor.

STATISTICS.*

The production of common bricks in the Hudson River district for 1883 and 1895 was as follows:

	1883.	1895.
Haverstraw,	311,396,000	238,000,000
Verplanck's Point,	73,750,000	25,000,000
Fishkill,	53,250,000	about same
New Windsor,	35,000,000	25,000,000
Rondout,	64,000,000	
Glasco,	27,500,000	50,000,000
Catskill,	32,250,000	
Catskill to Albany,	61,000,000	
Produced by new districts,	....	617,442,000
Total,	658,146,000	955,442,000

* All statistics quoted in this paper were compiled from Reports of the U. S. Geological Survey, and State Geological Reports.

The production of New York State in 1894 was 821,286,000, at an average price of $4.80 per thousand. In 1895 it was 955,442,000, at an average price of $4.60 per thousand. In 1896 it was [illegible], at an average price of $4.45 per thousand.

A comparison of these statistics, while it shows an enormous increase in the production for the last two years reported, shows also a remarkable diminution in the quantities supplied by formerly the largest producers of the lower Hudson River districts; the increase having been derived from the newer districts developed since 1883 at Dutchess Junction, Fishkill-on-Hudson and Roseton. The following table, compiled from personal inspection of the respective plants, is worthy of study:

Present Capacity (1897) *of Lower Hudson River Plants.*

	Bricks per Annum.
W. A. Underhill and Co., Croton Point,	20,000,000
Croton Co., Croton-on-Hudson,	12,000,000
Anchor Brick Co., Croton-on-Hudson,	10,000,000
Haverstraw,	238,000,000
Grassy Point,	40,000,000
Stony Point,	20,000,000
Bonner Brick Co., Verplanck's,	10,000,000
King and Lynch, Verplanck's,	10,000,000
W. A. Budd, Dutchess Junction,	10,000,000
G. H. Bonteon, Dutchess Junction,	7,000,000
G. W. Smith, Dutchess Junction,	5,000,000
Aldridge Bros. & Co.,	20,000,000
Covert Bros. & Co.,	5,000,000
Fishkill Brick Co.,	10,000,000
Timoney Tract Co.,	30,000,000
Denning's Point Brick Co.,	15,000,000
W. S. Aldridge, Fishkill-on-Hudson,	10,000,000
O'Brien and Vaughey, Fishkill-on-Hudson,	7,000,000
Brockway Brick Co., Fishkill-on-Hudson,	10,000,000
Dinan's, Fishkill-on-Hudson,	25,000,000
New Windsor and Cornwall,	
Rose, Roseton,	40,000,000
Jova, Roseton,	20,000,000
	574,000,000

This table includes only the principal plants in operation during 1897. Numerous small individual plants in this region have been neglected as unimportant.

Clay-Products as Materials for Construction.—A lump of common clay shaped into a brick was the foundation of architecture. Around the ruins of Babylon to-day examples of bricks are still being discovered, some well-burned, some vitreous. The form

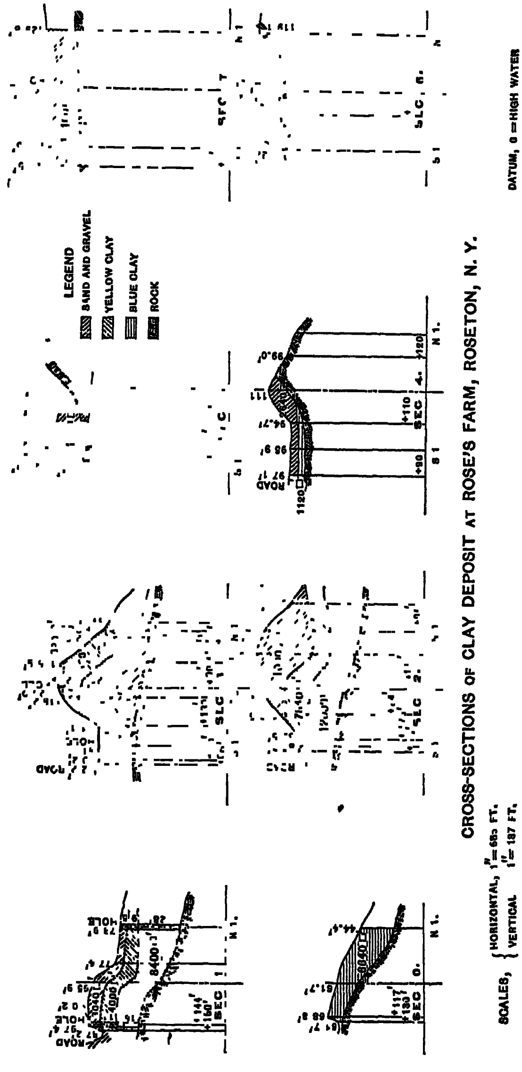


FIG. 20.

CROSS-SECTIONS OF CLAY DEPOSIT AT ROSE'S FARM, ROSETON, N. Y.

of a brick, and in a practical sense its size, is the result of ages of experiment. As a material for construction fulfilling the requirements of strength, durability, ease of manipulation and economy, the common brick will never be superseded. A well-burned brick made of clay is imperishable; will stand exposure

to heat, cold and moisture. It will outlast a civilization of which it will present the only indestructible remains. The facility with which bricks can be handled adapts them to every class of construction; their symmetry of form admits of use where no other material can be employed. With the improvements in construction resulting from engineering supervision, it is found that bricks can be made to comply with any ordinary specifications. As a matter of fact, well exemplified by the tall structures of to-day, the architect and engineer required a material with which to build, and bricks harder, better and cheaper than before have been the consequence. Various materials have been employed to accomplish the same result, without success. Common bricks have the property of adhering to the mortar used in laying them, to form a bond of great tenacity nearly equal in strength to the brick itself. For the given weight, strength, durability and economy it is a physical impossibility to supersede good bricks with any other form of structural material. The use of bricks, especially in communities of rapid growth, will increase proportionately. This demand is strikingly illustrated by the statistics cited further on, and in view of the facts discovered by this survey respecting the limitations of clay supply, attaches to the subject a commercial importance of vast possibilities hitherto unanticipated.

RECAPITULATION.

The following table summarizes the principal localities embraced in this survey.

Recapitulation of Clay and Sand at Principal Localities.

Locality.	Total clay. Cubic yards.	Total sand and gravel. Cubic yards.
Dutchess Junction,	15,572,856	1,245,425
Denning's Point,	1,356,999	28,000
Fishkill-on-Hudson,	8,544,147	1,401,552
Roseton,	9,523,923	4,485,332
Total,	34,997,925	7,160,309

This total is equivalent to 29,164,937,000 bricks, requiring 11,665,934 cubic yards of sand, and therefore indicates a deficiency of 4,505,625 cubic yards of sand. But the actual amount of sand and gravel commercially available far exceeds that given in the table, since the quantity of sand estimated

was only that within the limits of the clay-deposits surveyed and tested. At Fishkill-on-Hudson there is a notable deficiency of sand; but it is not improbable that the quantities available at Dutchess Junction and Roseton will far exceed the aggregate deficiency.

Computed on the above quantities, it will be seen that Dutchess Junction can produce 215,000,000 bricks per year for 60 years; Denning's Point, 20,000,000 per year for 50 years; Fishkill-on-Hudson, 125,000,000 per year for 60 years; and Roseton, 150,000,000 per year for 53 years, making a total of 510,000,000 per year, according to the actual estimates of this survey. Each locality will doubtless exceed this quantity of clay, as the estimates are all conservative and limited to the confines of the survey proper, without reference to a wide margin for each class of material not therein included. Upon this basis, it appears to be beyond question that these deposits can furnish an aggregate of at least 600,000,000 bricks per year, for a period of 60 years.

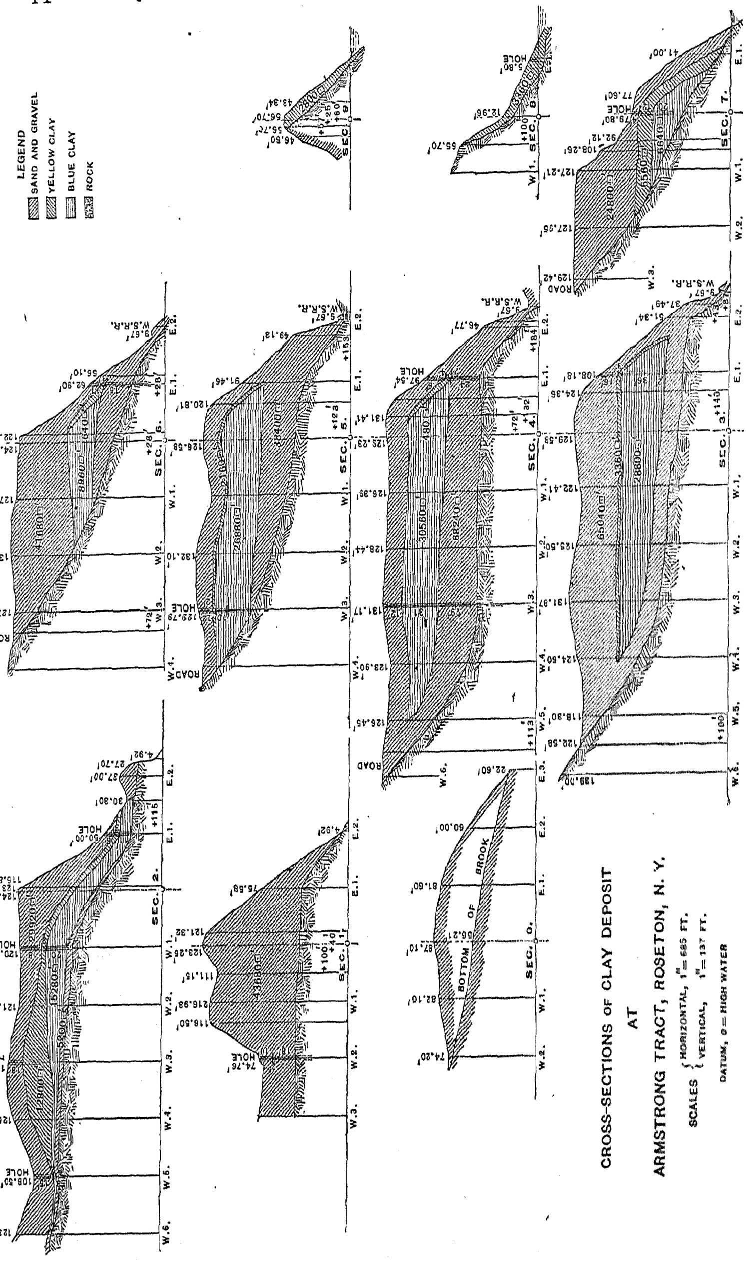
From the previous table, showing the present capacity of plants, it will be seen that Dutchess Junction, Denning's Point, Fishkill-on-Hudson and Roseton furnish 214,000,000 towards the total output of 574,000,000. This leaves 360,000,000 which can be furnished for at least five years by the other localities in Districts 1 to 6, inclusive. If an annual production of 510,000,000 be reckoned for the four districts named (in accordance with the above estimate of their capacity), the total product of the Hudson river valley from New York City to Danskammer Point will be 870,000,000 of bricks. An increase equaling the probable capacity of these localities, *i.e.* of 90,000,000 more, would give an aggregate total of 960,000,000 production for the lower Hudson valley districts, a figure in excess of the production of the entire Hudson river valley for 1895.

THE UPPER HUDSON RIVER VALLEY.

This study of the supply of clay in the lower Hudson river valley naturally suggests inquiry as to the condition probably existing in the districts above those covered by the present investigation. Until actual survey shall have been made it cannot be established that the contents of the deposits of the upper valley exceed what is known to exist in the lower valley. Superficial examination, largely aided by the physical

and geological facts already known, would indicate that the upper valley contains less clay than the lower. There is cer-

FIG. 21.



CROSS-SECTIONS OF CLAY DEPOSIT AT ARMSTRONG TRACT, ROSETON, N. Y.

tainly no evidence that it contains as much or more. For the purpose of a present economic estimate it is fair to assume

equal quantities respectively; that is, that the upper valley can also supply 600,000,000 bricks per year for 60 years. The whole valley would then be able to supply 1,200,000,000 per year for 60 years. But what will be the effect of increased consumption in a rapidly expanding community, now demanding nearly one billion bricks per year, and imperatively requiring a progressively larger supply for fire-proof construction, and taller buildings, with thicker walls and deeper foundations? What will be the duration of supply under such an increased demand? Unfortunately it is not possible to command accurate comparative statistics even for past periods. The collection of the data of brick manufacture is too recent an enterprise of our United States Geological Survey. A precise numerical forecast is, therefore, impossible at present; but a rough comparison may be made. Aside from an apparent increase in demand of 110,000,000 bricks per annum from 1894 to 1896, and an apparently indicated increase of 25,000,000 per annum in the ten years previous, the one known fact is a present production of practically one billion bricks by the State of New York, which is practically consumed by the city of New York. Economical investigations indicate a supply of practically one billion of bricks per year for a period of 60 years. If the demand should rise to double that quantity, the question of supply would acquire an intense practical importance. Who can predict the answer? Or, to put the same question in another form, When the Hudson river clay-deposits shall have been exhausted, where will New York City get bricks?

Conclusions.

In view of the facts above set forth, it is believed that a consolidation of interests, representing the principal districts of the lower valley of the Hudson, would effect an economy of production, together with a reasonable control of market conditions, which would be advantageous to producers and consumers alike, and would at the same time tend, through the employment of skill and system, to conserve the supply of a raw material so precious and so limited in quantity.

The Coking, in Beehive Ovens, of the Coals of the New River District, West Virginia.

BY CHARLES CATLETT, STAUNTON, VA.

(New York Meeting, February, 1899.)

HAVING had charge during the past year of the operations of the New River Coke Company, the second largest, if not the largest, coke-producer in this district, my attention was called particularly to the yield of coke from the coal as coked in a bank of beehive ovens, as the record showed that this yield, while believed to be well up with the practice of the district, was much lower than the analysis of the coal indicated it should be.

The coal is well known to many members of the Institute, and the scope of this paper does not include a discussion of its occurrence and development. It suffices to say that the New River district comprises the mines working on the coals of No. XII. or the Conglomerate Series of the Rogers brothers, which are located on New river and its tributaries, and which find an outlet for their product east and west over the Chesapeake and Ohio Railway. The New river through this section carries the drainage from an extensive peneplain in which it has formed a very striking and stupendous cañon, probably the most striking east of the Mississippi river. The only practical access to this territory is by means of this cañon and the Chesapeake and Ohio road, and the opportunities for development by other lines may be considered as *nil*. If it were not for the fact that this road, farther west, reaches and develops entirely different coals, which are found in other measures, the New River district might properly be spoken of (as is now done at times) as the "C and O. field." For fuller information on the geology of the region, those interested are referred to the very complete monograph on the subject by Mendenhall and Campbell of the United States Geological Survey.

The rocks are the same as those which carry the more widely

advertised Pocahontas coal, which is developed by the Norfolk and Western road; and it is quite probable that the beds are the same, and that the C. and O. but develops another portion. The New River and Pocahontas coals are very similar in chemical composition. The differences which exist are apparently all in favor of the seams developed on the line of the C. and O.; the coal, as a rule, carrying less ash, less sulphur, and slightly more volatile matter, than where it is developed on the Norfolk and Western. In the matter of ash, the clean coal is remarkably pure; the writer having examined numerous picked samples which carried less than 1 per cent. in ash. Mendenhall and Campbell report a number of analyses of what is known as the Sewell seam, the average of which is:

	Per cent.
Moisture,	0.73
Volatile matter,	26.43
Fixed carbon,	70.04
Ash,	2.46
Sulphur,	0.56
	100.22

The method of stating the sulphur differed in the several analyses from which the average was obtained. This explains why the average given is not in the usual form of a proximate analysis.

The coke of the district is made from slack-coal, which naturally carries an undue proportion of impurities; but, in spite of this, the coke will usually run only about 6 per cent. in ash. A shipment of coke made during 1898 by the New River Coke Company for special purposes, and from slack coal which had been screened to separate slate, etc., showed 4.23 per cent. ash. The coal from which this coke was made must, therefore, have carried about 3 per cent. of ash. This is sufficient to give an idea of the character of the coal in this particular. The material entering into the manufacture of coke will usually carry a larger amount of ash than this special shipment; but in all cases the coal makes a coke of special value for shipment to considerable distances, where the freight on even 1 per cent. of ash amounts to a good deal.

The sulphur, while variable, is usually quite low, running from 0.50 to 0.60 per cent., but often less.

Owing to the fact that the coke from this coal has been used to a very limited extent for the manufacture of Bessemer steel, little attention has been paid to the phosphorus-contents, and but few analyses have been made. Those which have been made show an exceptionally small amount of that objectionable element.

A coal of the average composition would theoretically furnish about 75 per cent. of coke. As a matter of fact, the majority of the ovens in the district do not yield 60 per cent.; and from the result of my investigations and my observation of other ovens, I am satisfied that many of them run less than 55 per cent.

This seems to be out of all proportion to what ought to be obtained, and indicates that, in addition to the volatile matter, about one-fifth of the coke is burnt up in order to secure the other four-fifths. It has been suggested by others that the insufficient amount of heat furnished by the gases alone might make it necessary to burn up a certain amount of the coke in order to complete the coking of the coal. I am not willing to admit that this is a fact; but, even if it be so, an undue amount is, beyond question, consumed. If comparatively smaller amounts of gas give smaller amounts of heat, it is all the more necessary to produce the largest possible amount of heat from the gases, and to conserve, in every possible way, what is produced. Far greater care is required in regulating the admission of air than is necessary with coals carrying an excess of volatile matter. It is obvious that if this could be so done as to coke the coal by the combustion of the gas alone, an enormous increase in yield and subsequent economy would result. I do not believe this is impossible.

The ovens of the New River Coke Co., which are bank-ovens, were built in 1888; and, while some of them have suffered from landslides, which are often a cause of damage in that section, they may be considered, as a whole, to be in good condition and to promise many more years of active service. They are not, however, in the best condition with reference to the retention of heat and the perfect regulation of the admission of air, so that a maximum yield cannot be expected.

Most of the ovens are 12 feet in diameter and 6.5 feet high on the inside. They are 30 inches high to the spring of the

arch. The doors are 2 feet 5.5 inches wide and 2 feet 3.5 inches high to the spring of the arch, which is 5 inches high, making a total height of 2 feet 8.5 inches. Some of the doors are 1.5 inch higher.

All the ovens are provided with draft-boxes. These are located on either side of the door, and are slightly deflected where they enter the oven, so as to be at right-angles to the axis on which the oven is constructed. Where these draft-boxes enter the oven, they intersect an arc of about 50°. The inlet is 6 inches wide by 5 inches high, and is closed with a sliding lid. Where the draft enters the oven the hole is 4 inches high by 7 inches wide, and the bottom of the opening is 4 feet from the floor of the oven. At least, this is true in most of them; the measurement in this particular does not seem to have been strictly followed.

In process of time these boxes have got into bad condition, being sunken, so as to deliver the draft against the coke, or closed up, etc. Personally I am rather in favor of draft-boxes. For purposes of anything like exact comparison, without an excessive amount of trouble, they are indispensable.

The following observations were made of the burning of a set of eight ovens by means of the draft-boxes, the observations extending over a period of about two weeks. The series 1 and 1*a*, 2 and 2*a*, etc., immediately follow each other. The series 1*b*, 1*c*, 1*d*, etc., were taken at another time, with the same ovens, and are in sequence, so that an examination of 1*b*, 1*c* and 1*d* will show the condition of oven No. 1 during each of three successive charges.

In these tables, "draft-boxes open" means an opening in each draft-box (a portion of the space being taken up by the slide) of about 5 by 5 inches. "Draft 2 inches" means that each draft-box has an opening of 2 by 5 inches. Where no measurement is reported, the draft is the same as in the previous reading.

As the ovens are burnt down, the process of the burning is fairly well shown by a well-defined line on the freshly-daubed door. This was measured in a number of cases, and indicates the number of inches, from the top of the door downward, that the coking had progressed.

At the time of the observations the ovens were, for reasons

Records of Coking.

		10 Hrs.	19 Hrs.	22 Hrs.	29 Hrs.	30 Hrs.	43 Hrs.	45½ Hrs.	50½ Hrs.	57 Hrs.	67 Hrs.	69½ Hrs.	72 Hrs.
No. 1...	Burnt out 24 hrs. before drawing. After charging, draft-boxes opened.	Burning free. Draft reduced to 1½ in.	Burning with short, smoky flame. Whitish in color.	Same as 19 hrs.	Draft 1¼ in., burning hot, with smoky flame. Door 18 in.	Burning hot. Draft reduced slightly Door 22 in.	Burning hot Draft increased to 1¼ in.	Draft increased to 1½ in.	Murky evening. Burning red and smoky. Door 26 in.	Hot and clear. Door 26 in	Hot; about burnt out; few small candles.	Drawn. Oven well burnt out, hot. Ends, as rule, perfectly clean and coke rather better than previous drawing.	
No. 2. .	Same as 1 to time of charging. Draft open.	Burning free. Draft reduced to 1½ in.	Burning with short, smoky flame. Reddish in color. Draft increased	Short, smoky flame. Reddish in color. Draft increased to 2 in.	Burning hot and dark. Draft reduced to 1½ in. Door 19 in.	Burning hot. Door seemed to be 20 in.	Burning hot, slightly smoky.	Slightly smoky. Draft 1½ in.	Draft increased to 2 in. Door 22 in.	Burning hot and clear Door 26 in.	Burnt off, except in spots.		Hot; finished drawing by 73 hrs. Coke fairly good. Some black ends, some perfectly clean.
No. 3...	Drawn when not quite burnt out. Charged, draft open.	Burning free. Draft reduced to 1½ in	Short, smoky flame. Whitish in color.	Burning hot and dark. Draft 1½ in. Door 15 in.	Door 19 in. Burning hot.		No change in door. As seen from top, burning hot; coke plainly visible.		Door 20 in. Draft 1½ in.	Burning hot and clear. Not so hot as 1 and 2. Door 26 in.	Door 27 in. Considerable flame all over oven.		Drawn. Good many black ends, and some unburnt coal in front of door. Most of the coke contained about 1¼ in., black end.

Records of Coking.—Continued.

		12 Hrs.	24 Hrs.	47 Hrs.	57 Hrs.	66 Hrs.	69 Hrs.	76 Hrs.	86 Hrs
No. 4	Charged 9 o'clock. Full draft.	Draft reduced.	Reduced to ¾ in. each box.	Draft same. From door burnt to 6 in. bottom.	Good deal blaze, but well advanced. Draft reduced to ½ in.	Well burnt down, but flame still coming off.	Long, whitish flame from middle and air burning coke. Draft almost cut off.	Quite hot. Small flame rising from center.	Drawn.
No. 5	Charged 9 o'clock. Full draft 12 hrs.	Draft reduced.	Reduced to a little less than 1 in.	Draft same. Door 8 in. from bottom.	Good deal blaze, well advanced Draft reduced to ½ in.	Well burnt out, but flame still coming off.	Long, whitish flame, right from center and air burning coke Draft almost cut off.	Burnt out.	Drawn.

		1 Hr.	4 Hrs.	9 Hrs.	12 Hrs.	20 Hrs.	28 Hrs.	34 Hrs.	40 Hrs.	46 Hrs.	50 Hrs.	54 Hrs.	56 Hrs.	61 Hrs.	70 Hrs.
No. 6	Stood 24 hrs. after burning out. Good coke. Well burnt, not well watered Oven stood some hours after drawing.	Draft 2 in.	Dark, not caught well. Draft reduced to 1 in.	Door shows 12 in.		Door shows 14 in.	Door 18 in. Burning dark and draft increased to 1½ in.	Burning hot. Very long flame.	Hot; long flame. Thin enough to enable one to see coke, looking through top.	Burning hot, but reddish and smoky. Draft 3 in. Door 30 in. Back draft from wind.	Burning very hot. Good deal flame.	Burning very hot. Still good deal of flame. Door 31 in.		Drawn. Burnt out well.	
No. 7	Oven not very hot when charged; had practically burnt out 24 hrs. previous.		Burning hot, slightly smoky.	Draft 1 in. Hot and black. Door 18 in.	Door 21 in.	Door 23 in.	Burning dark and draft increased to 1½ in.	Hot, but short flame.		Hot and strong, but thick. Cannot see down to coke. Draft increased to 1¾ in. Door 29 in.	Burning, slightly smoky and draft increased to 3 in.	Burning reddish and smoky, but hot. Door 31 in.	Burning hot, still slightly smoky.	Burning very hot, still slightly smoky. Door 31 in.	Flame still coming off. Drawn.
No. 8	Good coke. Well burnt out. Small amount black ends.	Boxes open.	Burning hot and smoky.	Door 16 in. Draft wide open.		19 in.		Burning hot, long flame. Night clear, cold, windy.							

Records of Coking.—Continued.

		5 Hrs.	9 Hrs.	19 Hrs.	26 Hrs.	32 Hrs.	43 Hrs.	53 Hrs.	69 Hrs.	93 Hrs.
1*a*........	Charged 12 o'clock. Draft-boxes wide open	Burning very hot Door 13 in.	Hot, long flame, hotter than 3*a*. Door 16 in.	Burning hot and thin. Hotter and thinner than 3*a* Slightly white flame. Door 18 in.	Draft reduced to 2 in.	Burning hot, slightly dark streaks. Door 24 in.	Burning hot; indications of thinning, but flame still long. Draft not changed. Door 30 in.	Door 31 in. Had reddish black streaks in flame.	Well burnt out. Door showing 31 in.	Drawn. Dark coke near door. Bottom burnt out clean. Coke shows cutting from draft.
2*a*........	Charged before 2 P.M. Draft 2½ in.	Burning black, but hot. Draft at 2⅓ in. Door 8 in.	Hot, quite smoky. Draft wide open, Door 10 in.	Burning hot. Still thick Door 12 in.	Draft reduced to 2⅔ in.	Burning hot, slightly smoky Draft increased to 3 in. Door 18 in.	Burning hot; indications of burning out. Still slight, dark streaks. Flame short. Door 30 in.	Draft unchanged. Hot: good deal of flame, but evidence of burning out. Door 26 in.	Almost out. Draft closed.	Drawn. Well burnt out. Some dark coke near door. As a whole burnt out clean.
3*a*........	Charged about 12 o'clock; left with hole over door 2½-in. vertical. About 12 in. long. Area about 18 sq. in. Draft-boxes open also.	Burning very hot Door 14 in.	Door 14 in.	Burning hot, with thin flame.		Hotter than 1. Door 8 in	About as hot, and flame as long as 1*a* Rather more burnt out Door 24 in.	Door 26 in Draft-boxes 2 in. About same time and about as much burnt out as 1*a*. Hole still over door.	About as much burnt out as 1*a* Draft still open. Door 27 in.	Drawn. Good coke. Some black ends and sponge. Appearance black ends indicate hot bottom.

Records of Coking.—Continued.

		6 Hrs.	11 Hrs.	17 Hrs.	21 Hrs.	23 Hrs.	27 Hrs.	31 Hrs.	34 Hrs.	43 Hrs.	50 Hrs.	57 Hrs.	67 Hrs.
No. 4*a*.	Charged at 9.30. Draft cut off to crack.	Draft opened wide.	Very hot. Draft rather strong Reduced to 2 in. Door 18 in.		Burning hot, but very smoky. Draft increased to 2½ in.	Still burning, smoky. Draft increased to 3 in.	Still darkreddish. Good deal back draft account of the wind. Draft increased to 4 in.	Burning hot, slightly smoky. Door 26 in.	Hot, long flame. Door 26 in.	Burning very hot, slightly smoky. Door 29 in.	Draft reduced to 2 in.	Burnt out, slight flame. Draft reduced to ½ in.	Drawn. Well burnt out.
No. 5*a*.	Stood a long time before charging. Draft open.	Burning hot, but draft seemed rather strong Reduced to 2 in. Door 18 in.		Burning hot and strong, but so smoky draft increased to 2½ in. Door 18 in.	Draft increased to 3 in.	Burning hot. Long flame, slightly smoky. Draft increased to 3½ in. Door 26 in.	Burning very hot. Long flame	Not very long flame. Door 28 in.		Burning hot, very thin Door 28 in.	Draft reduced to 2 in.	Burnt out. Hot. Closed. Few candles or small flames. Door 31.5 in.	Drawn Well burnt out.

		23 Hrs.	31 Hrs.	34 Hrs.	49 Hrs.	54 Hrs.	57 Hrs.	71 Hrs.	73 Hrs.	90 Hrs.
No. 6*a*.	Charged. Draft-boxes 3¾ in.	Burning very hot, long flame. Door 22 in. Draft reduced to 2 in.		Door 25 in Burning hot and strong, with black streaks in flame.	Burning, with hot, short flame Well burnt out Coke plainly visible from top Door 26 in.		Well burnt out. Draft reduced to 1½ in.		Very small amount blaze from middle Draft closed.	Drawn.
No. 7*a*.	Charged. Draft open.	Burning hot, long flame. Coke visible from top. Door 21 in.	Burning hot and strong; long, smoky flame. Draft reduced to 2 in. Door 30 in.		Burning hot Not so far advanced as 6*a*. Good deal back draft. Door 30 in.	Door 32 in. Draft reduced to 1½ in.		Oven hot Good deal blaze still coming off. Draft reduced to ¾ in		Burnt out. Drawn.
No. 8*a*	Charged Oven hot. Draft open.	Burning hot, long, white flame. Draft reduced to 2 in. Coke visible from top. Door 14 in		Door 16 in Burning hot, strong and thin. Can see coke.	Door 18 in Draft unchanged. Burning hot, short flame. Well burnt out.	Door 24 in. Good deal back draft. Burning hot and thin.		Good deal blaze still coming off. Draft reduced to ¾ in.		Burnt out. Drawn.

Records of Coking.—Continued.

	Morning.	Evening.	Morning.	Evening.	Morning.	Evening	Morning.
No. 1b.	Charged. Draft-boxes wide open.		Burning very hot and thin. Draft reduced to 3 in. each box.	Still burning very hot. No change.	Burning hot and thin Draft reduced to 1⅓ in.	Almost burnt out Draft unchanged	Drawn Said by drawer to be well burnt out
No. 2b.		Charged about 3 o'clock. Not very hot. Draft 2⅓ in.	27 hours after burning very hot Slightly thinning. Draft reduced to 1½ in. each box.		Draft 2⅓ in	Burning hot, but a good deal of gas and with considerable dark streaks.	Oven was hot, but not well burnt out Good many black ends.
No. 3b	Charged.	Not hot at 3 o'clock P M Both boxes open wide.	27 hours thinning Draft reduced to 3 in each box.		Burning well and hot Draft not changed	Burning well and hot Draft not changed Gas thinning Good deal gas.	Drawn and charged, and caught by 9 o'clock Coke showed considerable amount thin black ends
No. 4b.	Charged.	At 3 o'clock not burning much. Draft 2⅓ in.	27 hours afterwards burning hot Draft reduced to 1⅓ in.		Draft 2⅓ in Burning badly Opening in top of door corresponding to about 5 sq in.	Burning hot Enough draft, but oven seems not to have heated up well. Slight black streaks.	Drawn. Good many black ends, but pretty well burnt out.

	Morning.	Evening.	Morning.	Evening.	Morning	Evening	Morning.
No. 5b	Charged. Oven hot. Draft, over door, average 12x2 in. Key block reaching down so as to turn draft down.	Burning hot, long, reddish flame.	Very hot: too much draft. Well advanced Draft reduced to an average of about 12x1 in.	5 P M. Burning very hot In good shape Draft reduced to 10x½ in.	Burning hot and thin Good shape		Drawn and charged by 9 o clock Showed small number black ends, and on the whole in good shape Good coke
No. 6b.	Draft 3 in.		Burning very hot. Draft 3 in. each box.	Burning very hot, indication too much draft. Boxes unchanged.	Very hot, quite thin. Draft reduced to 2 in	About burnt out Hot, small amt. flame coming from about center Draft reduced to 1 in.	Drawn about 4 o'clock Said by drawer to be well burnt out
No. 7b.	Charged. Draft open wide.		Burning very hot: evidence too much draft Reduced to 3 in. each box.	Burning very hot, long flame, thick slightly red. Draft unchanged	Hot and still Draft reduced to 2 in	5 o'clock burning hot and thin, but still good deal gas and smoky appearance Draft seems to be burning coke Draft unchanged	Drawn about 6 o'clock Coke usual grade Stated by drawer to be entirely burnt out
No. 8b.	Charged. Draft open wide.		Burning hot; evidence too much draft. Reduced to 3 in. each box.	Burning hot, long flame. Just enough draft.	Burning hot and thin Draft reduced to about 2 in	5 o'clock entirely burnt out Closed Draft seems to have burnt coke.	Drawn by 9 o'clock Strange to say, the drawer claims that this was less burnt out than 6b or 7b, but still he says it was well burnt out On whole, up to average in quality

Records of Coking.—Continued.

	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.
No. 1c.	Drawn by 9 o'clock. Charged by 10 o'clock. Hole over door 14x1 in.	11 o'clock P.M. Burning very hot, long flame.	5 o'clock. In good shape: burning, with long, reddish flame, little dark Draft unchang'd.	Burning hot, very thin; large hole in coke from draft. Draft considerably reduced, 14x½ Heavy rain during night.	Oven burnt out, with exception few candles right in middle. Well burnt out elsewhere and cooling. Draft cut off Large hole in coke from draft.	Oven cooling.	Drawn morning by quarter to 9. Coke good quality. Fairly clean bottom.		
No. 2c.	Drawn and caught up by 9 o'clock. Draft-boxes wide open.	Burning very hot, with a larger flame than 3c and a good deal hotter; indications rather too much draft.	Burning quite hot, good shape, too much draft. Reduced to 3 in.	Burning very hot. Draft reduced to 2 in.	In good shape. Burning hot and beginning to get thin Draft reduced to 1½ in 11 o'clock very hot, thin. Almost burnt out.	6 o'clock. Well burnt out, and getting cool. Back of oven indicated wet, cold bottom. Draft cut off.	Drawn some time after 9 o'clock.		
No. 3c.	Drawn and caught up by 9 o'clock. Opening oven door 12x2 in.	5 P.M. Burning hot, with dark-red color. Prob. enough draft for 96 hrs. coke.	Burning quite hot, but darkish streaks; believed to be about right 96 hr. coke. Draft not changed. Hotter than 4c.	Burning hot. Draft not changed. Not so hot as 2c.	Burning in good shape. Just about enough draft. No change.	11 o'clock P.M. Good shape, burning very thin, rather far advanced.		5 P.M. Considerable flame coming up about to top in a lazy way. Oven not as hot as should be No change in draft.	Drawn 5 A.M Large, heavy, good coke, but indication of coal bottom, and not burnt out well.
No. 4c.	Drawn by 10 o'clock. Draft-boxes closed.	Oven smothered with dark-reddish flame. Draft-boxes open wide.	Burning hot, but dark. No excess of draft, rather smothered. Draft not changed.	Burning hot. No indication of excessive draft, which was, however, cut down to 2 in.	Oven rather smothered. Not very hot. Draft increased to 2½ in.	11 P.M. Long flame. In good shape.		6 o'clock. Good deal flame, but burning in good shape. Flame rising pretty rapidly No change in draft.	Drawn by 9 o'clock Good shape. Dark ends, but no unburnt coal. Good coke. Drawer says not quite burnt out.

Records of Coking.—Continued.

	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.
No. 5c.	Drawn by 9 o'clock. Charged and caught by 10 o'clock. Hole over door. Average about 12x¾ in.	11 P.M. Burning hot, long flame. No indication of excessive draft. About right.		6 P.M. Condition about same. Draft not changed.	Good shape. Draft unchanged.	7 P.M. Hot, long flame, quite thin No indication excessive draft, but owing to time has to run, draft reduced to 10x½ in	Well burnt out, with the exception of small flame right down middle. Oven cooling Large hole in front of door. Draft cut off Not near so hot as 1c.	Oven cooling.	Drawn, charged and caught up by 9 A.M. Well burnt out. Good coke Badly watered.
No. 6c.	Drawn about 4 A.M. Oven hot.	Charged. Late in afternoon burning well. Draft-boxes 8 in.	Burning just about right, maximum heat; rather too much draft for the length of time it has to go. Reduced to 2 in.	11 P.M. Long, luminous flame, but well advanced and thinning.		6 P.M. Burning very hot, thin and indication will be burnt out in next 12 hrs. Draft reduced to 1 in.	Small amount flame coming off direct from center Oven cooling	7 P.M. Oven well burnt out, hot No indication excessive burning from draft-boxes, but, as seen above, large hole directly in front of door, indicating leakage	Drawn and coke loaded by 8.0 Said by drawer to be well burnt out.
No. 7c.		Charged after standing about 9 hrs. Burning well late in evening. Draft-box 8 in.	Burning hot and in good shape. Drafted just about right for maximum heat, but well burnt out before time. Reduced to 2 in.	11 P.M. Burning hot, long flame, very hot. Draft not changed.		6 P.M. Burning very hot, long flame. No indication of excess of air, but seen down through the thinning blaze indication that draft was burning coke Draft unchanged.	Good shape Good deal flame, but coming off rapidly, and oven hot.	7 P.M. Oven hot Few candles in middle, but, as a whole, well burnt out. Draft cut off to ½ in	Drawn and loaded by 8.30 Identity of coke lost
No. 8c.		Charged after standing about 9 hrs. Burning well late in evening. Draft 3 in.	Burning well and hot. Well advanced. Too much draft for the time it has to run. Reduced to 2 in.	11 P.M. Burning very hot and thinning.		6 P.M. Burning at a white heat and quite thin. Indication draft burning coke. Too much draft Draft reduced to 1 in. in each box.	9 o'clock. Burnt out Hot. Closed	7 P.M Burnt out and clean.	Drawn by 9 o'clock Unusual amt. of bright, redeposited carbon. Coke right in middle at point maximum thickness, burnt out well, but in spite of long heat and high standing considerable black ends Probably due to irregular bottom Very small amt of sponge Coke in very unusually long, thin, columnar pieces.

Records of Coking.—Continued.

	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.
No. 1*d*.	Drawn and charged by 10 A.M. Draft open wide.	Burning very hot.	Hot. Good shape. No indication excessive draft. Draft not changed.	Burning hot, thin and red. No indication excessive draft. Reduced to 3 in.	No change in draft.	Burning very hot and very thin. In looking down into same no indication of excessive draft Draft cut off	Drawn and charged by 8 45 Good shape Good deal sponge, but good bottom.
No. 2*d*.	Drawn and charged after 9 o'clock. Draft-boxes open.	7 o'clock. Burning well and hot, long flame.	Burning hot, long flame, rather too much draft. Oven good condition. Draft unchanged.	Burning well and hot. Flame short. Too much draft. Reduced to 3 in.	Good condition. Short flame, thinning, very hot Little too much draft for maximum heat. Reduced to 2 in.	Almost burnt out Good deal of flame coming out of top, but oven very hot.	Drawn and charged by 8 30. Drawer states that not well burnt out. Coke badly watered, and showing at same time excess of thin, black bottoms.
No. 3*d*.	Drawn 5 A. M. Charged about 9 A.M. Draft wide open.	7 P.M. Burning hot, long flame.	Hot, long flame. Good condition. Draft unchanged.	Very hot, rather too much draft. Reduced to 3 in.	Burning hot, long flame, thinning somewhat. No indication of excessive draft Draft reduced to 2 in.	Good deal of flame still coming off, but oven hot.	Said by drawer to be not entirely burnt out Considerable black ends Coke rough looking Drawn and charged by 8.30.
No. 4*d*.	Charged about 9 A.M. Draft 1 in.	7 P.M. Hot, but dark, rather smothered. Draft 2½ in.	Draft 5 in.	Burning hot, but with smoky flame. Draft 3 in.	Burning very hot, long flame, rather too much draft. Draft reduced to 2 in.	Thinning and very hot, but more flame coming out than either 2*c* or 3*c*.	Drawn about 9 o'clock. Considerable black ends in spots. Coke rough-looking.

Records of Coking.—Continued.

	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.
No. 5*d*.	Drawn, charged and caught up by 9 A.M. Draft open wide. Indication of leakage over door.	Burning hot, long flame.	Burning hot, long flame. No indication of too much draft	Hot. Thin, but no indication of excessive draft.	About burnt out, hot Draft reduced to 2 in	Entirely burnt out, hot. No indication of excessive burning at any point	Drawn and charged by 8 45. Coke good.
No. 6*d*.	Drawn and coke loaded by 8 30 A.M. Stood number of hours before charging. Draft open.	5 o'clock. Just catching up well. Little or no smoke coming out top.	Burning hot, long, dark flame. Draft unchanged.	Burning hot, but dark. Draft unchanged.	Burning hot, but dark streaks No indication of too much draft Draft unchanged.	In good shape, hot Some flame. Draft not changed.	Drawn before 5.30 Well burnt out. Good coke. Rather more sponge than usual.
No. 7*d*.	Drawn and loaded by 8 30.	5 P.M. Burning hot and smoky.	Burning hot, slightly dark, long flame Draft reduced to 3 in	Good shape, hot.	Thinning, burning hot and darkish streaks. Hotter and in better shape than 6*d*. Draft increased to 3½ in.	Good shape, but with good deal flame coming out. Draft unchanged.	Commence to draw 5.30. Said by drawer to be well burnt out, with exception one spot. Coke, on whole, very good, and clean bottoms, but some black ends.
No. 8*d*.	Drawn and loaded by 9 o'clock. Draft 3 in.	5 P.M. Burning hot. Draft wide open.	Burning hot, light-colored. Comparatively short flame Draft reduced to 3 in	Good shape, very hot. Indication too much draft. Reduced to 2 in.	Thinning, very hot Good shape.	Good shape Practically burnt out.	Drawn by 9 o'clock. Good coke. Good shape. Well burnt out. Small amt. sponge. Good deal bright, redeposited carbon.

Records of Coking.—Continued.

	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.
No. 2*e*..	Drawn and charged by 8.30. Draft wide open.	Dark. Good shape. Not particularly hot.	Hot. Good shape. No indication of excessive draft.	Hot, long flame. Possibly too much draft, but not changed.	Draft reduced to 3 in.	Good shape. Hot, short flame. Draft reduced to 2 in.		Burnt out and oven cooling. Indication cold and wet bottom.	Drawn and charged by 8.30. Good coke.
No. 3*e*..	Drawn and charged by 8.30. Draft open.	Not very hot, but good shape.	Hot. Good shape. No indication of excessive draft.	Good shape. Hot, long flame. No indication too much draft. Good deal back draft.	Hot, thin. Draft reduced to 3 in.	Draft reduced to 2 in.		Burnt out. Oven cooling. Small amt. flame coming from center and back. Large hole from draft-boxes. Indication rain had run in. Draft unchanged.	Drawn and charged by 8.30. Good coke, but cold bottom.
No. 4*e*..	Drawn about 9 A.M. Draft open.	Dark, but burning in good shape.	Hot. Good shape. No indication of excessive draft.	Ditto. Long flame and hot. Good deal back draft. Draft unchanged.	Hot, thinning. Draft reduced to 3 in.	Reduced to 2 in. Burning about as 2*e*. Hot, thinning. Rather too much draft.		Burnt out. Cooling.	Drawn by 9 A.M. Good coke, but indication damp bottom.

	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.	Morning.	Evening.
No. 5*e*..	Drawn and charged by 8.45.	Good shape.		Good shape. Hot. Draft reduced to 3 in.	Good shape. Hot, thinning. Rather too much draft. Reduced to ½ in.	Burnt out. Large hole from draft-boxes.		
No. 6*e*..	Drawn and charged. Draft open.	Good shape. Hot, long flame. Rather hotter than 7*e* and 8*e*.	Hot, slightly smoky. Draft not changed.	Appeared to be about in condition 2*e*. Burning hot, short flame. Draft reduced to 3 in.		Hot. Good shape. Thinning. No indication of excessive burning from draft-boxes. Reduced to 2 in.	Oven cooling. Small amt. blaze right from center. Heavy rain the night before.	
No. 7*e*..	Drawn and charged. Draft open.	Burning. Fair shape. Rather hotter than either 6*e* or 8*e*.	Hot. Good shape. Draft not changed.	Very hot, thin. Draft reduced to 3 in.		Very hot. Very thin. No indication of excessive burning. Draft reduced to 2 in.	Drawn. Burnt out. Oven hot.	
No. 8*e*..	Oven not as hot as 6*e* and 7*e*. Draft closed.	Burning dark. Draft open.	Hot. Good shape. Rather too much draft. Reduced slightly.	No indication of too much draft, but reduced to 2½ in.		Good shape. Draft not reduced.	Burnt out and cooling. Drawn.	

not necessary to be discussed here, working on 72-hour and 96-hour coke. The charges for 72-hour coke averaged 10,640 pounds, and for 96-hour coke 11,312 pounds. All coal was accurately weighed.

The ovens represented in the preceding records were selected as being most convenient to the office. They were afflicted with cold bottoms which had a tendency to become wet from only a small amount of rain. They were exceptionally difficult to burn out so as to give clean bottoms over the entire oven. "Black ends" do not mean unburnt coal, but dark-colored coke for a distance of 0.5 to 1 inch from the bottom.

It must be confessed that the figures given in these tables are by no means conclusive on any point; but they show what a small amount of air is at times necessary to burn out the oven in the proper time; and they have been productive of much good in directing attention to the excessive draft which had formerly been used, and have also served to call attention to the necessity of protecting the ovens from small leakages, and to emphasize the fact that every pound of air going into the ovens unnecessarily is a source of loss. They have also served as a basis for other investigations, of which circumstances did not permit a record, and have been, it is believed, instrumental in effecting an increase in the average yield for the year of 4 per cent. more than the ovens had ever produced before.

Some tests were also made with reference to the size of the ring, which was originally very large, and which in many cases had been worn even larger. The serious loss of heat from this source does not seem to have been fully recognized. Rings of various sizes were experimented with, the smallest being about 11 inches in diameter. The results with this size were quite good, but the general indications were that it was a little too small; and 12 inches is believed to be about the right size for this coal and these ovens.

It was also observed that several of the ovens, which had been rebuilt with a slightly higher crown, burned uniformly better and hotter; and the writer is satisfied that, for this coal, a 12-foot oven should not be less than 7 feet high. He believes that when ovens are built with reference to this particular coal, with the best possible protective covering, with a view to saving all of the heat possible, and with special provision for regulat-

ing the admission of the air and its more perfect exclusion when desired, a very much larger yield can be secured from this coal, and advantage would then be derived from its high carbon-contents.

This result cannot be secured without having, in charge of the draft, a man of more intelligence than can be commanded by ordinary laborer's wages; but it will be found to repay the investment. One per cent., saved on the yield of a reasonably large block of ovens, would more than pay the salary of a good man; and 5 or 6 per cent. of increase in yield would mean a satisfactory profit. This increase is well within the range of possibility, as the present practice is not, as a rule, the result of careful investigation of the peculiar character of the coal.

Biographical Notice of Oberberghauptmann Dr. Albert L. Serlo.*

BY PROF. DR. HERMANN WEDDING, BERLIN, GERMANY.

(New York Meeting, February, 1899.)

ALBERT LUDWIG SERLO was born February 14, 1824, at Crossen-on-the-Oder. After completing his school-studies and his training as a mining official, he received in 1851 an appointment as Royal Manager of salt-works (*Salinenfactor*) and member of the Administration of Salines at Königsborn, near Unna, Westphalia. The issue of new regulations for the training of higher State officials in the Department of Mining, Metallurgy and Salines, led him to pass in 1856 a special examination for the rank of *Assessor*, in consequence of which he was called to Berlin, to serve for a few months as an assistant in the Ministry of Commerce, which had charge of mining, etc. In the same year he became *Bergmeister* and member of the mining administration at Bochum, Westphalia, and in 1858 *Oberbergrath* and member of the provincial administration, called the *Oberbergamt*, having its headquarters located at Dortmund. In 1861 he was appointed Director and head of the newly-reorganized mining

* Translated by the Secretary, and translation approved by the author.

administration of the important governmental coal-mining district of Saarbrücken.

From this period dates his famous activity as a mining official. It was in 1860 that Krug von Nidda, a man who played in the mining and metallurgical affairs of Prussia and of Germany the rôle which Bismarck played in their foreign relations, took control as Oberberghauptmann of the Prussian mining administration. To him these great interests owe their deliverance from fettering limitations, and the consequent advance which has now brought Germany, in this department, to the second place among the nations. Serlo was one of the few who, from the first, correctly appreciated and put into practice the principles of Krug von Nidda. By so doing he made the State collieries at Saarbrücken a pattern and example for the world.

After a temporary service at the ministry in Berlin, he was sent in 1866 to Breslau as Director of the *Oberbergamt* there; and in this new position he carried out again, with brilliant results, the ideas of Krug von Nidda.

The period passed in Berlin exercised a decisive influence upon his literary work, and laid the foundation, doubtless, of a wider fame beyond the limits of his native country than that which his administrative achievements earned for him at home; for it was at this time that he undertook, upon the death, in 1866, of Lottner, the first Director of the Royal Academy of Mines, founded by Krug von Nidda at Berlin, to arrange and edit for publication Lottner's lectures on the art of mining. The first edition of this work appeared in 1868, after Serlo had assumed his post at Breslau. It has passed through several editions since, and still maintains its position as a leading treatise on the subject.

After the resignation of von Nidda, in 1878, Serlo succeeded to the office of Oberberghauptmann and Director of the Prussian Department of Mining, Metallurgy and Salines. The supreme authorities in the kingdom were amply justified in the belief that, for the place of the great public servant who had passed away, no more worthy and efficient occupant could be found than the man who had so effectively seconded and executed his plans.

This expectation was fulfilled by the event. To say nothing

of his generally efficient and progressive administration, Serlo achieved a work of conspicuous and lasting importance by creating the now celebrated commission for the investigation and remedy of the dangers due to fire-damp in coal-mines. As the president of this commission, and an active participant and guide in its work, which resulted in the promulgation of rules and precautions now followed in nearly all countries, he deserves to be regarded as a benefactor of colliery-workmen throughout the world.

Unfortunately, it was not long before an insidious spinal disease began to destroy his ardent enjoyment in his work, and in 1884 it forced him to retire from active service. In spite of the severe sufferings which made him physically a cripple, he lived for years, under the devoted ministrations of his wife, in undiminished mental vigor. But at last his strength and her nursing could no longer avail, and death released him on November 14, 1898.

Serlo's distinguished achievements in the foremost German mines and metallurgical works, and his masterly recension of Lottner's *Bergbaukunde*, have assured him a place among the great exemplars and leaders of the profession which he adorned. It was his good fortune to know, during his lifetime, that his merits were universally recognized, as was abundantly evidenced by the numerous orders and honorary memberships which were bestowed upon him. Among the latter, none gave him deeper gratification than his election as Honorary Member of the American Institute of Mining Engineers.

The Longest Mine-Haulage.

BY F. Z. SCHELLENBERG, PITTSBURGH, PA.

(New York Meeting, February, 1899.)

A RECENT visit with the engineering students of the Western University of Pennsylvania to the Keeling coal-mine on the south side of Pittsburgh furnished interesting matter to communicate, as may be the case, however, with regard to the striking features of any of our well-arranged larger collieries; for every mine surely appears unique as a whole, though description fails to give that impression, except in particulars.

In the first place, the deliveries of the product at the terminal are on a paved street of the city, and not to railroad-cars, or to river-boats, as they might be, from such a gravity-plane as the mine-cars descend, coming from the old drift-mouth at the outcrop of the coal-seam, fully 350 feet above the river-level. The dumping is into road-wagons that travel the streets. A total of about 200,000 tons is handled in a year.

Standing where the cars emerge on the hill-side, we see the smoke-stacks in the valley occasionally giving out great black clouds; and while we know that this means a loss of only 1 per cent. of the fresh fuel, we feel annoyed at the thought of the discomfort to the inhabitants that could be avoided if the users would obey very simple rules of applied science, using, for example, heating-furnaces of adequate capacity, that would not require pushing but only steady, small dosing of fuel. This reform would require in many cases the increase of the steam-boiler plant. When we turn to think of the waste in the ground, we would invoke some power against individual wantonness.

But whatever may have been the loose method of mining in these front hills, the Keeling mine is now worked to get all the good coal of the seam.

We take passage in the train of 60 mine-cars and ride through three hills and over short intervening ravines, drawn by a 16-ton steam-locomotive, for 2 miles. The enlarged tunnel, so called, is 10 feet in bottom width, 8 feet top, and 9½ feet high, where it is timbered. The track-rails weigh 60 pounds to the yard.

Here, at Spiketown, stands a rope hauling-plant, idle since last October. The 8 miles of ropes were wound up on the drums when the electric trolley-line displaced their work, with the promise also of a farther reach than the nearly 3 miles, the trebled length of which had often called for a mile's renewal at a time.

At Spiketown, too, is Dr. Slocum's experimental gas-plant for furnishing a substitute for natural gas, when this product of our day shall have reached its time of displacement, or rather replacement; for in this case it cannot be displaced by an article superior to that which came so easily from nature's store to our lavish hands.

The electric locomotive seems to have come to stay. Two of these are employed, each making its trip in an hour (at the rate of 8 miles per hour while running), and bringing a distance of 3½ miles a train of 30 cars against a grade of 1 per cent. maximum. Each car with its load weighs 2 tons. The gauge of the track is 39 inches. One locomotive runs in and the other out at the same time, the trains passing inside.

In the next ravine stands the new power-plant; two Westinghouse direct-current, compound-wound, multipolar, belt-driven generators of 100 K. W. each, at 250 to 300 volts. The two prime motors are Fischer steam-engines.

Westinghouse-Baldwin locomotives are used, each equipped with two 50 H. P. motors and weighing about 25,000 pounds. With that weight on the drivers 15 per cent. is expected to appear as pull on the draw-bar; and 10 pounds pull to the ton for the locomotive, with 18 to 20 pounds per ton for the mine-cars, are required on the level on the well-laid track. With inferior road-bed and superstructure, and common mine-cars in bad repair, 40 pounds pull per ton on level track would be the initial rating, before considering the effect of grade. At Keeling's, therefore, there is no more power called for up the 1 per cent. grade than would be required under common conditions without grade.

The Westinghouse Electric and Manufacturing Co. declare that, "except at the instant of starting, the draw-bar pull is practically the same for all speeds up to 12 or 15 miles per hour, uniform speed. When the train is accelerating, an additional draw-bar pull is necessary to overcome the inertia."

The track in the mine is partly laid with 40-pound rails.

The 7 miles of nearly all underground mine-car haulage, including the gathering by mules in the mine itself, it is almost needless to say, is in good alignment, the result of proper surveys. The entries are 8½ feet wide by 5½ feet high.

The electric current is utilized to advantage for incandescent lamps at the parting- and in the waiting-rooms (for such they have here, cleanly, and fitted with benches to sit on); and it may soon find further uses, as a trial is being made with two under-cutting machines, of two makes of endless-chain cutters, that do the kerfing in the upper half of the lower bottom of the coal-seam, which bottom it was not advisable to work by hand

as the whole of it would be taken, and would put an inferior product among the lump-coal. The full 5 feet of breast—above the lower bottom "beared in"—is thus now all making lump-coal.

In this mine the pillars between rooms—the ribs—will not be robbed and then left to waste, as is done too much now in "machine mines" in the harder coal, and always was done in the softer coal. Everybody ought to know that the pillars can all be consecutively safely mined as easy work by hand, and that leaving ribs, whether purposely to waste or in postponement, jeopards the open work and threatens it with ruin by squeeze.

On Lick Run, shipping on the Wheeling branch of the Baltimore and Ohio Railroad, is another Keeling mine, which is working northward; and there may be in a few years 10 miles of open main entry, through the junction of the two fronts.

Near that farther front are other railroad coal-mines; and the "First Pool coal" comes from that rear country, where the hills round about rise more than 500 feet above the river-level.

The Gold-Bearing Veins of Bag Bay, Near Lake of the Woods.

BY PETER MACKELLAR, F.G.S., FORT WILLIAM, ONTARIO, CANADA.

(New York Meeting, February, 1899.)

I. Introduction.

The district around Bag bay in Shoal lake, west of Lake of the Woods, in the Ontario western gold-fields, is attracting considerable attention at the present time as a gold-producer. A large number of gold-bearing veins have been prospected and mined to a considerable extent in the locality. On the whole they make a fair [illegible] considering the work done; and some are undoubtedly rich—the Mikado, for instance. The principal mining companies that have been operating here are the Yum-Yum, Ontario Limited, Cornucopia, Engledue Concession, Tycoon, Toronto and Western and Mikado Cos. I will confine my remarks chiefly to the three companies last

mentioned, as their developments, lying in the Bag bay granite (which is several square miles in extent), present the peculiar feature which this paper is intended to describe, namely, the smallness of the quartz-fissures as compared with the size of the ore-bearing lodes. Most of the operations of the other companies are within Huronian areas, and if the veins which they are working were formed under similar conditions, as I think they were, the peculiarity referred to is not so strongly marked.

II. The Geological Formation.

The geology of the western gold-fields of Ontario has been fairly well established by the Canadian Geological Survey and the Ontario Bureau of Mines. Dr. Bell commenced the real work in the Thunder Bay District in 1869 and in the Wabigoon and Lake of the Woods Districts in 1881, and made the first geological map of these regions. He showed that the rocks belong to the Archæan age, which comprises the Laurentian and Huronian systems. The gneisses and the principal acid eruptives were classed as Laurentian; while the green schists in general, and the basic eruptives, were provisionally included with the Huronian.

The work was ably continued by Messrs. A. C. Lawson, W. McInnis, W. H. Smith and others. Now the whole district from Thunder bay to the Manitoba boundary, a distance of more than 300 miles, is pretty thoroughly mapped out, so as to show its principal geological and topographical features. Through the gneisses and schists, granite, syenite, protogine, etc., have been erupted in great bosses and irregular areas. These, again, have been intersected by dikes of felsite, diorite, etc., and, still later, by numerous fissure-veins, which, in many localities, are gold-bearing.

III. Mining Developments.

The Mikado Mine.—The well-known Mikado gold-mine is situated on the south side of Bag bay. It has been in successful operation with a 20-stamp mill during the last eighteen months. Three veins on the property, Nos. 1, 2 and 3, are worked. In the report of the Ontario Bureau of Mines for 1898, page 53, Mr. Breidenbach, the general manager of the company, reports as follows:

"On No. 3 vein the shaft has been sunk 45 feet and is being continued. It has enlarged from several inches at the top to 5 feet at the bottom, and the assays run from $1 per ton at the surface to $7 at the bottom, increasing gradually. . . . . No. 1 and No. 2 veins have been mined to a depth of about 250 feet each. No. 2 vein, at the surface, is only 2 to 3 inches wide of quartz, but rich—$100 to $200 to the ton. At a depth of 100 feet the lode is 6 feet wide, of $10 per ton ore."

This ore is principally the green veinstone, mikadoite, to be described further on. At 240 feet deep the lode is larger, 6 to 12 feet wide, and yields $15 to $20 to the ton. I have confirmation of these particulars from reliable sources. No. 1 showed an unusually large outcrop of quartz for this class of veins. It was a high-grade ore, $45 or more to the ton.

During surface-developments, the ore was believed to be free-milling, and only amalgamated copper plates were used for saving the gold. About two months ago, the erection of a cyanide plant with a capacity of 50 to 60 tons per day was commenced. It was completed about the middle of November last. It has been installed by Mr. J. C. Pengilly, a gentleman of large experience in South Africa and other parts of the world. Now it seems that only about one-third of the gold is free-milling in the deeper workings of the mine. In answer to my inquiry, Mr. Pengilly kindly informed me by letter that the first run of the cyanide process was very successful, 77 per cent. of the gold-contents being recovered.

I know no more convincing proof of the value of these veins than the statement of Mr. Breidenbach in the Rat Portage *News*, about six weeks ago, that there was a twenty-five years' supply of ore in sight in the mine, which has not been worked over two years, during eighteen months of which time a 20-stamp mill has been in operation. The value of the ore worked up to the present date, as near as I can find out, is $15 to $20 per ton. Very rich ore has been struck in the lower level which will average many thousand dollars to the ton. When last reported they had taken out several tons of it, and still the body was getting larger. I have handled samples of the ore which felt heavy with the gold, like the Calumet and Hecla ore, with its native copper.

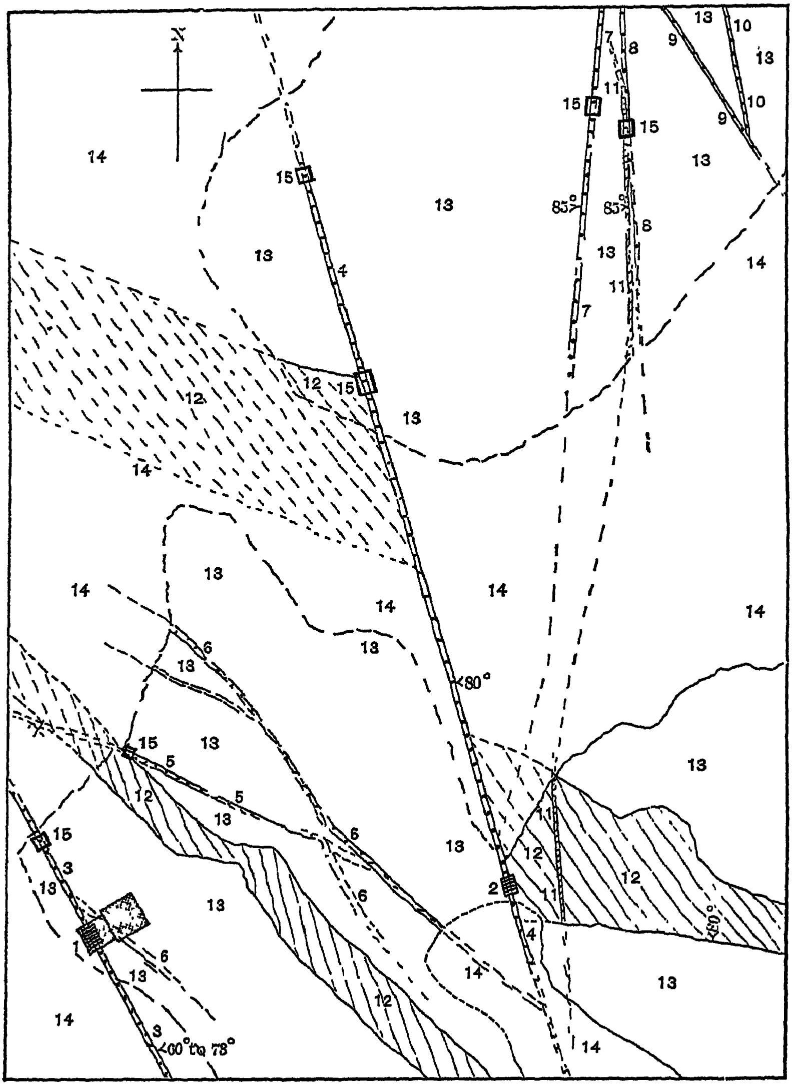
The Toronto and Western Mines Development Co.—This company owns the Sirdar mine, on location "D 410," [illegible] the Mikado mine on the east; also several other contiguous locations, "D 411," "D 412," etc., all situated on the granitic area,

and many other locations throughout the Ontario Western gold-fields. As Field Superintendent of this company, and also as connected with its development-work for the last two years, the writer has had many opportunities for examining the formations and veins.

The Sirdar and "D 411" properties are each one-half mile square. On the latter location several test-pits were sunk on different veins to a depth of 5 to 8 feet each and a 7 by 11-foot shaft was sunk to a depth of 57 feet. On the Sirdar several veins have been examined by sinking test-pits to a depth of 5 to 8 feet, and two shafts have been sunk, one on No. 1 vein to a depth of over 100 feet (now in progress of development with a steam hoist), and the other on No. 2 vein to a depth of 57 feet. The veins occur in groups, one of which appears on "D 411" and two on the Sirdar location. Of the latter, Fig. 1 shows the western one, Group A. These veins appear on the surface like stringers of quartz, rarely reaching a width of more than six inches. They are traced with difficulty for any great distance along the surface, yet when opened up by mining they generally show two, three, six or more feet in width of gold-bearing ore, a greenish veinstone which I will call mikadoite for convenience of description in this paper. This veinstone seems to be a talco-siliceous mineral resembling sericite. It appears to have been formed by the alteration of the granite. Its color is greenish-white to green; it is massive and slightly unctuous, and merges into the quartz as if they were one mineral. When light in color it is called quartz by the miners and others generally, but it is easily detected by its yielding readily to the knife and leaving a white powder. It first became conspicuously noticeable in the Mikado mine, and it forms the principal productive portion of the gold-veins in the Sirdar group. All these veins upon which work has been done are much alike in character, but they vary in size and richness.

Quartz, in irregular stringers, lenses and lumps, occurs throughout the mikadoite, more plentifully in some parts than in others. There are also occasional stringers of dark-green chlorite, one-half to one inch wide. The mikadoite penetrates the granite in several places in the shaft which are not marked in the section, as only the outshoots, where I had taken measurements, are shown.

FIG. 1.



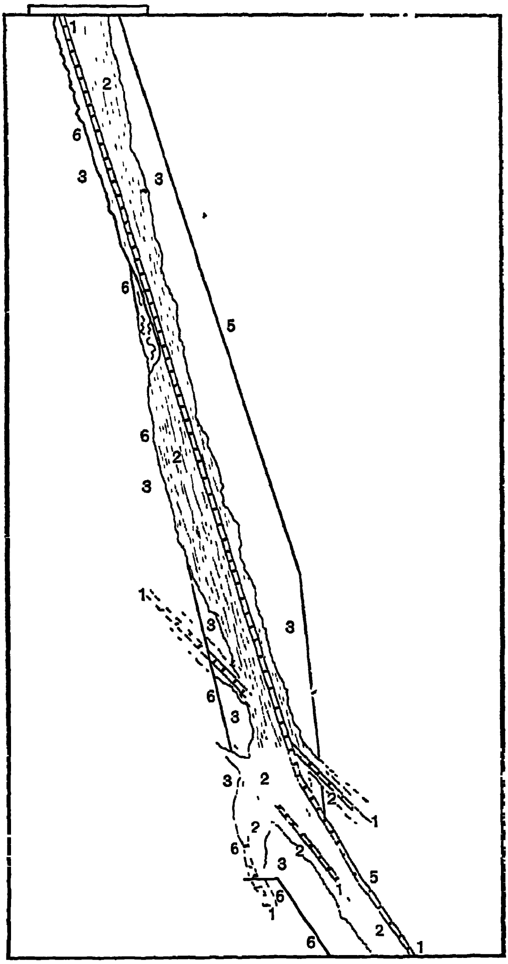
Group of Veins, Sirdar Gold Mine—Scale 1650, linear, to 1.

1. Shaft and shaft-house on No. 1 Vein. 2. Shaft on No. 2 Vein. Shows lateral throw of over 200 feet. 3. No. 1 Vein. 4. No. 2 Vein. 5. Vein, 3 in. quartz and 2 to 3 ft. mikadoite. 6. Quartz stringers with mikadoite. 7. Vein No. 3, Quartz 4 to 10 in. and mikadoite 5 ft. 8. Vein, 3 to 4 in. quartz; 2 to 3 ft. mikadoite. 9, 10. Quartz veins, 4 to 5 in. wide. 11. Chloritic-diorite dike, 4 to 12 in. wide. 12. Felsite dikes. 13. Granite. 14. Covering of alluvial deposits. 15. Test-pits.

The shaft is now down to the 100-foot level. At the surface the principal sheet or vein of quartz was on the foot-wall, with

the mikadoite above it. It continued on a straight line, at the dip of 73 deg., to a depth of 85 feet, with a strongly marked wall. At this point the mikadoite is below it, and more than seven feet wide. At 60 feet depth there was about 1 foot of

FIG. 2.



Vertical Section of Shaft on No. 1 Vein—Scale 240, linear, to 1.
1. Quartz vein. 2. Mikadoite. 3. Granite. 5. Hanging-wall of shaft. 6. Foot-wall.

mikadoite above and 3.5 feet below the quartz sheet or vein. The latter varies from a couple of inches to four or five inches in width. The amount of vein-quartz through the mikadoite is irregular and varies considerably.

The ore in bulk in the upper portion of the vein, chiefly mikadoite, averaged about $4 per ton, as was shown by a test of about 45 tons treated at the Keewatin reduction-works. Again, by sampling a pile of about 30 tons of the ore taken from a depth of 65 to 80 feet, and another pile of 25 tons from a depth of 80 to 90 feet, the yield on assay was found to be $4 in the former and $24.20 in the latter. The assays were made by Mr. Charles Brent, of the Rat Portage metallurgical works. I have made many pan-tests of the ore from this shaft, and have found the gold much coarser from the lower part than from the upper. It does not appear that there is much change in the richness of the pure quartz; but the mikadoite seems to improve very much in value below the depth of 70 to 100 feet. The work in the Sirdar and Tycoon mines shows this, and I have reliable information that this mineral is much richer in the lower part (below the 100-foot level) than it is in the upper part of the Mikado No. 2 vein. I may also mention that samples of mikadoite from the Sirdar shaft, below 80 feet in depth, assayed in Toronto, gave more than $300 to the ton.

The Tycoon Mine.—This property is a water-location of about 60 acres, enclosing three islands in Bag bay, immediately in front of the Mikado and Sirdar mines. It lies across the strike of the veins of the Mikado and of those of group A of the Sirdar. On these islands three diamond-drill holes were sunk to vertical depths of 108, 128 and 152 feet respectively, and each intersected a group of veins. Mr. James Conmee, M.P.P., kindly showed me the results of the borings, which confirm to a remarkable degree the impressions I had formed as to the principles governing the formation of these veins. The vein-outcrops would be passed over as unworthy of notice, even by mining prospectors, unless they had previous knowledge of this class of veins. Only small veins of pure quartz are shown; and the greenish veinstone, or mikadoite, which accompanies the quartz, differs but slightly in appearance, on weathered surfaces, from the granite. The surface-samples I have panned showed very little gold; and yet, below the 100-foot depth, where the diamond-drill cut the veins, they are very rich, as will be seen by the description given below.

I expected a fair showing of gold at the depths where the drill would intersect the veins, by reason of the results of the

developments obtained on shore; but I had no expectation of such a remarkable showing as the actual tests presented. The first bore-hole, at a depth below 120 feet, intersected a vein 11 feet wide, which assayed an average of $19 per ton. It then passed through 24 feet of granite and intersected another vein-belt, 20 feet wide, that assayed an average of $13 per ton. The second bore-hole was placed about 300 feet east, to intersect a second vein. This hole passed through two vein-belts separated by 46 feet of granite. The first belt is 60 feet wide, of siliceous schist, or mikadoite, assaying $4 per ton. Within this schist are seven quartz-veins, each 1.5 to 4 feet thick, an aggregate of 19 feet of quartz, which yielded by assay an average of $67.25 per ton. The whole width of the vein-belt, 60 feet, gives an average of $24.10 per ton. After passing the granite, a second vein-belt is reached. This is 20.5 feet wide, and gives an average assay of $37.65 per ton. One branch of quartz in this belt, 4.5 feet wide, averaged $150 per ton; another, 6 feet wide, gave $7 per ton, and the balance $5.50 per ton.

The third hole reached a vertical depth of 108 feet. The first vein-belt intersected was 26 feet wide and assayed $6.70 per ton; the second vein-belt, below the 100-foot level, was 6 feet wide, and assayed an average of $16.50 per ton.

IV. Vein-Characteristics.

These veins consist of small quartz sheets with comparatively large quantities of the altered granite (mikadoite) which shows a schistose structure next to the quartz, and passes by gradual transition into massive granite. It is generally charged with fine iron pyrites amounting to 0.5 to 3 per cent., and carries more or less gold, in grains and not in leaves, as it is in the quartz in some places. Small quantities of the sulphides of copper, lead, zinc and bismuth are occasionally present, more particularly in the quartz, rarely in the mikadoite. The latter accompanies the quartz fissure-veins and spreads out irregularly to either side, apparently following lines of weakness or lines along which the granite was most frequently jointed, and thus forms great bodies of ore. The veins are shown to be true fissures by the faultings of the formations. Along No. 2 vein, Fig. 1, the felsite dike is displaced laterally over 200 feet. Again, they intersect alike the massive and stratified formations.

The felsite dikes are charged more or less with gold, adjacent

to the quartz-veins, without being otherwise much altered, except that they have an increased percentage of iron pyrites. Samples taken at the surface from the felsite dike cut by Sirdar No. 2 vein yielded by assay over $6 per ton, and pan-tests of the same at the depth of 50 feet were much richer; but this dike has not been tested with a view of finding how far the gold penetrates into it. Some of the smaller dikes that traverse the Huronian strata are gold-bearing also. Several of these, which intersect the diabase masses, are being mined with promising results. For instance, Inspector Bow, in the seventh report of the Ontario Bureau of Mines, says, in regard to the Ontario Limited mine, that No. 4 vein appears to be a felsite dike; that it has been traced for 500 feet, and shows in one place where it has been uncovered a width of 12 to 14 feet; also, that a test-pit has been sunk 9 feet upon it, and a quantity of ore has been taken out for a mill-run. Again, in reference to the Gray Eagle mine, he says (p. 59) that the ore-bodies are large felsite dikes which contain a few stringers of quartz.

V. The Source of the Gold.

It seems highly probable that the gold was derived from heated vapors and solutions that ascended through the fissures from great depths, presumably from the vicinity of the magmas, the source of the felsites and greenstones. The felsite dikes are generally present near the veins, and are usually more or less charged with the fine-grained sulphide of iron that almost invariably accompanies the gold in the veins. They are also frequently auriferous, and especially so in the near vicinity of quartz veins. The felsite in many places loses its visible texture and passes into phonolite with the usual metallic ring. It is probable that this rock has some connection with the presence of the gold here, as I understand the phonolites of the famous Cripple Creek are admitted to have in that region. And, somewhat similarly, the trappean eruptions are connected with the presence of the Lake Superior native copper. For these reasons I have great confidence in the continuance and improved value in depth of the auriferous veins just described.

VI. Principles of the Vein-Formation.

In my examination of these veins I was for a long time unable to understand the nature of their formation, nor did I find

the conditions presented to agree with the ordinary fissure-vein theories of which I had any knowledge. I came at last to the conclusion that, during the movements that caused these rents, a sufficient pressure was exerted to prevent such a separation of the walls as would leave an opening or gap for the reception of vein-matter. Therefore the opening must have been created afterwards. There can be no doubt that the rock masses which were involved in creating the fissures must have been enormous, and that the granulation and lamination of the walls would be a natural consequence. Subsequently the heated solutions that would surely percolate among the fissures and interstices would be likely to dissolve the more granulated portions for the reception of the silica or usual vein-quartz, while the other crushed portion would be metamorphosed, as is well represented by Professor C. R. Van Hise in his admirable paper on "Metamorphism of Rocks and Rock-Flowage."

Again, Dr. M. E. Wadsworth, President of the College of Mines, Houghton, Mich., says, in his pamphlet on the Lake Superior Copper Deposits, 1891:

> "One of the latest phases of the formation of deposits of value has been the filling in of fissures by the water-deposited quartz and other vein-materials, or, in case no crack nor fissure existed, by the removal of the country-rock along certain lines and their replacement by vein-matter."

I have noticed a great difference in the character of these gold fissure-veins of Archæan times, and those of later age, such as the silver-bearing veins of Thunder bay. The latter show well-defined walls, frequently with brecciated extraneous matter enclosed in the quartz or sparry matrix, while the adjacent rocks are but slightly, if at all, laminated or metamorphosed. The veins in the Archæan rocks, on the other hand, rarely show two well-defined walls and seldom contain extraneous brecciated matter, and the adjacent country-rock is generally laminated and highly metamorphosed. The laminated portions are, in many places, an important factor in the gold-veins of the latter class, as shown by these of Bag bay. There may be veins of later age within the Archæan areas, but there cannot be any of Archæan age in the areas of newer rocks. I believe that the gold-veins of the western Ontario gold-fields were formed in Archæan times, as I know of no place where they

penetrate the later formations around the basin of Lake Superior. They occur in the Archæan areas on both sides of the lake, as at Jackfish bay, at Schreiber and on Shebandowan lake on the north side, and again at the Ropes gold-mine, north of Ishpeming on the south side, but not in the later rocks which lie between the last-mentioned and the others. Although it does not appear that there are gold-veins in the newer rocks (Cambrian and Silurian) in the Lake Superior country, it is in rocks of later age than the Archæan that gold is chiefly found in other parts of the world.

VII. Sawbill and Hammond Reef.

I believe that many other localities throughout this vast area of gold-bearing rocks in the western Ontario gold-fields will be found to be subject to similar geological conditions in regard to vein-formations. I will only refer to one locality which lies along the Seine river in the vicinity of Sawbill lake. I have spent considerable time in exploiting the gold-veins in that district. The rocks are somewhat similar to those at Bag bay, and consist of Huronian strata and eruptive rocks. The principal eruptive is an altered granite or protogine, in which chlorite takes the place of mica. I noticed in several of the quartz-veins here the same greenish siliceous veinstone (mikadoite) as that in the Bag bay veins; and it is also auriferous in many places.

It seems probable that the granitic rocks of these two localities were erupted from the same or similar magmas at about the same geological time. At both places they are intersected by similar dikes of felsite and diorite. Out of many auriferous lodes here, I will refer only to one, the well-known Hammond reef. This is a remarkable gold-bearing belt. It is 100 to 500 feet in width, and traverses the country for miles, separating into branches that diverge at considerable angles. The gold-bearing portions are largely mikadoite, with branches of quartz. It seems to have been formed under similar conditions to those of the Bag bay veins. Here there appears to be a series of nearly parallel fractures, close to each other. The mechanical forces that were in action were not equal to reducing the whole to a sufficiently crushed condition to be effectively acted upon by the heated solutions. Hence the unreduced portions appear

as enclosed barren cores within the reef. According to the hypothesis explained above, the reefs or lodes should improve in depth.

VIII. Peculiarities of the Archæan.

As I have endeavored to point out, these Archæan metalliferous deposits are different from the general metalliferous formations of the world; and it appears to me that the gold-bearing fissure-veins are marked examples characteristic of the former.

Considering the early age of the Archæan rocks in the history of the globe, the crust at that time must have been thinner and weaker, the heat greater, the gaseous elements more powerful, and the shrinkage of the crust more rapid and intense, than in later times. Therefore, it might be expected to find the rock-formations greatly fractured, and the sides of the rents ground and laminated to a greater extent than in veins of later date. Although there may be veins of the open-spaced fissure-kind here, I think the majority are of the other variety, in which the space for the reception of the vein matrix was created by solvents in the water circulating through the crushed material along the fractures. In the latter case, the size of the quartz-vein is not a fair standard of the strength, value or continuity of the lode, when judged by the principles of formation and filling of fissure-veins of later formation. The lamination of the walls is, I think, a guide by which to distinguish the two kinds of veins. I am strongly of the opinion that mining men and experts in general will be mistaken if they look for the general characteristics of the open fissure-vein among the Archæan rocks of the western gold fields of Ontario.

In conclusion, I may say that the doubts which existed as to the continuance downwards of the gold-deposits in these Archæan rocks have about vanished within the last two years. I think that, upon consideration of the showing made here, it will be conceded that the auriferous deposits of the western Ontario gold-fields promise to improve in depth—more, probably, than those of any other gold-mining country in the world. The deeper into the veins, the more effective should have been the crushing and granulating process; and, proportionally, the quantity of both quartz and mikadoite ore should be greater also.

The Patio Process in Guanajuato, Mexico.

BY ROBERTO FERNANDEZ, M.E., GUANAJUATO, MEX.

(New York Meeting, February, 1899.)

WANT of knowledge on the part of experts from abroad respecting the [illegible] known as the Mexican or patio process, has been the cause in this country of trouble to many foreign mining companies. This process has not been looked upon by their managers as a satisfactory method of treating silver-ores, and they prefer to employ others, which, although more modern, and often more profitable in other countries, have not proved to be so under the exceptional conditions of this country, where labor is cheap and paid in silver, while fuel is very dear. The cause of this error of judgment is probably the inexact information which has been furnished by several authors respecting the economical results of the patio process.

This treatment is not suitable for silver-ores of every kind. Simple sulphides of silver are best adapted to it, and, next to these, the combinations of complex sulphides, viz., pyrargyrite, polybasite, stephanite, proustite, etc.

Chlorides, bromides and iodides of silver are considered rebellious; argentiferous galena, blende, bournonite, as also argentiferous arsenical pyrites of iron and copper, are absolutely unsuited to this treatment.

Experience has proved that high-grade ores do not give as satisfactory results as those of medium grades, as, for instance, carrying from 1 to 2 kilos of silver per metrical ton.

The patio process, as actually practiced in this district, comprises the following operations:

1. The ore is crushed in a dry state in a roller-mill, reducing it to pea-size, from which uniform samples, and, in consequence, correct assays, can be obtained.

2. It is then thrown into the arrastra, and pulverized with water, so fine that it will pass through an 80-mesh screen.

This operation has a double object: to reduce the ore to very fine pulp, without which a thorough amalgamation is impossible, and at the same time to collect the gold on the amalgamated bottom of the arrastra.

3. The ore is treated in the patio.

4. The pulp is washed to collect the amalgam in the settler.

5. The amalgam is retorted to separate the silver from the quicksilver.

6. The silver is melted and assayed.

Not wishing to make this paper too long, I shall only enter into explanations relative to the third step of the process, namely, the treatment of the ore in the patio. The other parts would be of little interest to the Institute, since any of the methods commonly used in the United States are applicable to them.

Treatment on the Patio.—The patio is a large enclosure, paved with great care, and made as impenetrable to mercury as possible.

After the ore has been finely pulverized it is taken into the patio, where it forms what we call the *torta*, a mass of circular shape, 30 centimeters, more or less, thick, and containing from 100 to 250 metrical tons of ore. The *torta* should contain sufficient water to dissolve the chemicals, but at the same time it must be of such consistency that it will not allow the mercury to settle on the bottom.

The chemicals used are chloride of sodium and sulphate of copper.

The amount of salt used is from 40 to 60 kilos, and that of sulphate of copper from 4 to 6 kilos per metrical ton of ore. Mercury is used at the rate of 8 kilos for each kilo of silver in the *torta*.

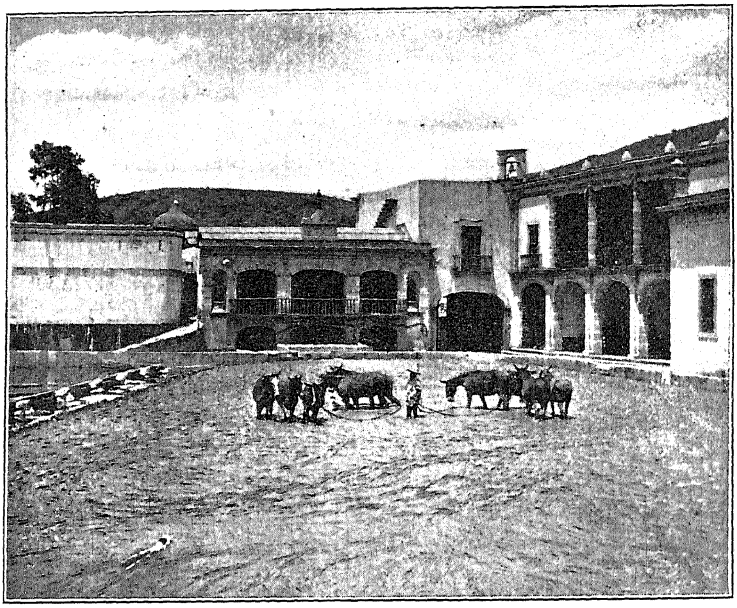
The salt and sulphate of copper are first applied, after which the quicksilver is added, scattering it in the minutest possible atoms, with the object of distributing it over the whole surface of the *torta*.

The chemicals are thoroughly mixed with the *torta* by the treading of mules, an operation which is called *repaso*. Many attempts have been made to employ machinery in place of the mules, but none have met with success. Fig. 1 is a view of

the patio at the *Hacienda de San Javier*, showing the mules treading the *torta.*

Theory of the Reaction.—The reaction at once commences. All the authors who have dealt with this matter have discussed at great length the question, What chemical reaction actually takes place in the *torta?* But up to the present time no exact and certain determination of this question has been reached.

Fig. 1.



The Patio at the Hacienda de San Javier, Guanajuato, Mexico.

The chief differences of opinion are, whether the formation of chloride of silver takes place or not; whether it is the chloride or the bi-chloride of copper which plays the principal part in the formation of the chloride of silver; and whether the bi-chloride of copper produced at the expense of the chloride of copper is the chief factor in the reduction of the ore.

The theory usually adopted here is the one advocated by the learned professor of chemistry in the State College of this city, Don Vicente Fernandez,* who, in view of the practical re-

* *Práctica del beneficio de minerales de plata auríferos usado en el distrito de Guanajuato-Llamado de patio. Estudio remitido a la Sociedad Mexicana de Historia Natural, por su socio corresponsal, Don Vicente Fernandez.*

sults generally obtained, and the many experiments made with the greatest care by himself, admits the formation of chloride of copper and the chloruration of the silver, but in the form of sub-chloride. The sub-chloride is dissolved in the excess of chloride of sodium and then reduced to a metallic state by the mercury, and chloride of mercury is formed.

Prof. Fernandez recognizes the following reactions:

$NaCl + CuO, SO_3 = NaO, SO_3 + CuCl.$

$CuCl + 2AgS = S + CuS + Ag_2Cl.$

$Ag_2Cl + 2Hg = Hg_2Cl + 2Ag.$

Or,

$2NaCl + 2CuO, SO_3 = 2NaO, SO_3 + 2CuCl.$

$2CuCl + 2AgS = 2S + Cu_2Cl + Ag_2Cl.$

$Ag_2Cl + 2Hg = Hg_2Cl + 2Ag.$

Or, starting from the last equation but one,

$Cu_2Cl + 2AgS = 2CuS + Ag_2Cl.$

$Ag_2Cl + 2Hg = Hg_2Cl + 2Ag.$

This theory of sub-chloruration is in accordance with the practical results obtained. It calls for the loss of only one equivalent of mercury for one of silver; and practically the loss of mercury for one kilo of silver is 1.116 kilos, of which 1 kilo is the chemical, and 0.116 kilo the mechanical loss.

The most important objection which has been made to this theory is, that it cannot be that chloride of copper is in fact formed, since, were it present, it would attack the mercury in preference to the silver, and the loss of mercury would be much greater than it really is. Prof. Fernandez offers the following explanation in reply to this objection:

If chloride of copper, sulphide of silver and mercury are placed together, the last is attacked directly; but if a small amount of quartz-powder (which principally forms the matrix of the ore of which the *torta* is composed) is mixed together with the three above-mentioned bodies, the mercury is then not attacked, and the amalgamation of the silver takes place. He infers that the matrix of the ore prevents the chloride of copper from attacking the mercury, and thereby allows the amalgamation.

Assays.—Three kinds of assays are used to find out how the treatment is working, namely, the *tentadura*; the assay of the amalgam, and the assay of the residue.

A *tentadura* is made by taking small portions from as many different parts of the *torta* as possible, and washing them in a wooden bowl, varnished black inside. A rotary motion is given to the bowl, whereby the lighter particles are carried off, and the heavier ones deposited on the bottom in the order of their specific gravity. Three parts will then be distinguishable in the *tentadura*, which are called respectively *el boton* (the button), *el cuerpo* (the body), and *la cabeza* (the head).

The head contains in its extremity, or exterior part, the *liz*, which is the quicksilver in a state of powder, part of it being probably in the form of chloride of mercury. In the center it usually contains *limadura*, that is to say, amalgam of silver in a thick white brilliant powder, which has not yet been mixed either in the *torta* or in the *tentadura* with the rest of the amalgam; such mixture having been probably prevented by its peculiar molecular state.

The body is composed of iron pyrites, but it also contains *limadura*, principally in the parts nearest to the head.

The button is the globule of amalgam, varying in size in proportion to the amount of the pulp with which the *tentadura* has been made, and more or less liquid inversely, according to the amount of silver that has been amalgamated.

The amount, color and consistency of these parts indicate the state of the *torta*, what chemicals are still wanting, the amount of silver that has been amalgamated, and, lastly, when the treatment is at an end.

The assay of the amalgam is made by weighing a little of it, taken from the *torta*, and, after having expelled the mercury, weighing the silver that remains.

The treatment is considered at an end when the amounts of silver and mercury contained in the amalgam are in the same ratio as the silver and mercury contained in the *torta*, allowing for the loss of mercury that has taken place in the treatment, which, as already stated, is 1.116 kilos for each kilo of silver treated.

This assay, however, is not always to be absolutely relied upon. If anything unusual has taken place in the treatment, it will not be exact. The assay of the residue is therefore made.

This is done by washing a little pulp and separating the amalgam. The residue or powder left behind is then assayed;

and by comparing the grade of this with that of the *torta*, it can be exactly ascertained what amount of silver has been amalgamated.

When the treatment is finished, the *torta* is washed, the amalgam retorted, and the silver obtained smelted and assayed.

The tailings are concentrated in an apparatus called a planilla—a table upon which the operation is performed entirely by hand.

The whole treatment of the ore lasts from about three to six weeks, the time being longer in winter than in summer.

Costs.—The following is the exact cost of treating the ore in the *Hacienda de Luna* during a period of six months, in which 2531 metric tons of ore, carrying an average of 1.123 kilos of silver per ton, were reduced.

Cost of Patio Treatment Per Metric Ton.

General expenses of management,		$0.58
Coarse crushing,	$0.69	
Fine grinding in arrastras,	1.28	
	——	1.97
Manipulation in "patio,"		0.44
Washing in settlers and retorting,	$0.39	
Assays,	0.28	
Planillas,	0.20	
Direct taxes,	0.38	
Sundries,	0.85	
	——	2.10
Fodder for mules,		3.93
Quicksilver,	$2.34	
Sulphate of copper,	0.77	
Salt,	1.32	
	——	4.43
Total cost per ton,		$13.45

The average loss of silver in treatment was 6.25 per cent. and of quicksilver 1.116 kilos for each kilo of silver extracted.

The consumption of chemicals was 4 kilos of sulphate of copper and 55.5 kilos of salt for each ton of ore.

Notes on the Geology of Sonora, Mexico.

BY E. T. DUMBLE, HOUSTON, TEXAS.

(New York Meeting, February, 1899.)

INTRODUCTION.

In the *Bosquejo Geológico de México*, published in 1897 by the *Secretaria de Fomento* as Nos. 4, 5 and 6 of the *Boletin del Instituto Geológico de México*, the Director, José C. Aguilera, after a detailed account of the geological observations made by himself and his assistants on their several trips through the various districts of the Republic, gives in Part 2 a synopsis of the geology of Mexico, describing all the formations recognized, the rocks comprised in them, their geographical distribution, disturbances, principal eruptions and economic features, as explanatory of the Geological Map of Mexico. In Part 3 Prof. Ordoñez describes many of the interesting eruptive rocks of Mexico.*

This work brings together in a very satisfactory way about all of the published results of geological investigations in Mexico; and although the determinations of the authors with reference to some of the sedimentary deposits are very different from those of other writers, they seem to be based upon good paleontological grounds in each instance.

From the map and the text of this paper it appears that the condition of knowledge in regard to the geology of the State of Sonora, at the time of its publication, was about as follows:

The western portion of the State, lying between the coast line of the Gulf of California and the foot-hills of the Sierra Madre mountains, is largely Quaternary, interrupted by areas of Azoic rocks and of later eruptives, with two or three limited exposures of limestones of the Cretaceous; while the eastern or

* A translation, by Oliver C. Farrington, of numerous extracts from the paper of Ordoñez, will be found in the *Journal of Geology*, vol. v., p. 467.

mountainous portion of the State is covered principally by post-Cretaceous eruptive rocks, with relatively small exposures of Azoic, Triassic, Cretaceous and Tertiary beds.

The Azoic rocks include the older granites, syenites, diorites and pegmatites, which occur chiefly in the Altar and Hermosillo districts.

In neither map nor text is there any mention of deposits referable to the Paleozoic era as occurring in Sonora, no sedimentary beds of earlier age than the Triassic being described.

To the Triassic are referred the beds of sands and clays, with their included deposits of graphite and coal, which are exposed around La Barranca and Los Bronces, and westward to San Marcial in the Hermosillo district.

The Cretaceous limestones observed in the districts of Altar, Hermosillo and Arizpe are considered the equivalent of the Comanche series of Dr. C. A. White.

The knowledge of the Tertiary deposits is limited to certain conglomerates and breccias, principally of igneous rocks, which are tentatively referred to the Pliocene because of their stratigraphic position. No fossiliferous beds were observed.

The widespread beds of Quaternary origin are unsorted gravels, sands and silts.

In the description of the eruptive rocks, all, outside those mentioned as occurring in the Azoic, are referred to as of post-Cretaceous origin.

During a visit to the State in the early part of 1898 I had an opportunity of observing some further facts regarding its geology which are, in part, presented herewith as a contribution to the fund of general information concerning Sonora, which State promises, under intelligent and systematic development, to become one of the richest portions of our sister Republic, both in mining and in agriculture.

Route.—Our first trip began at Batamotal, a small station on the Sonora railway, eight miles north of Guaymas, and our route took us over the lowlands bordering the coast to the town of Potam, on the Yaqui river. We followed this extremely fertile river-valley through Torin and Bocum to Cocorit, where we turned south toward the Mayo river, crossing that stream a few miles west of Camoa, and from there drove to Alamos.

After a few days' stay in Alamos we started north, and, recrossing the Mayo near the mouth of the Cedros, which is its main affluent, continued up that stream until we reached the hacienda of Cedros, making a number of stops and side-trips *en route.* From Cedros we again crossed to the Yaqui by way of Batacosa and Baroyeca, reaching the river at Buena Vista—a locality which certainly justifies its name. Crossing the river at this point, we drove to La Barranca by way of Cumuripa and Suaqui Grande. With this point as a base of operations, numerous trips were made for general examination of the region, and we then drove to Hermosillo through Tecoripa, Casita and Zubiate. On this trip I had the assistance of Mr. J. Owen, of Eagle Pass.

The second and shorter trip was made from Nogales by way of Santa Cruz, San Pedro and La Morita to the eastern border of the State north of Fronteras. We returned by the same route.

GENERAL GEOLOGY.

I. CENOZOIC.

As remarked above, the only Cenozoic beds recognized in Sonora by the Mexican geologists were those of Quaternary age, and some conglomerates which were tentatively referred to the Pliocene. No other sedimentary beds later than those of Mesozoic age were known to exist.

Pleistocene.

The deposits of the Pleistocene are unsorted gravels and sands, derived, for the most part, from the country-rock immediately adjacent to the deposits, and silts or marly clay, usually in massive beds and without lines of stratification. Among the deposits referred to this period, Aguilera makes special mention of the calcareous tufa, which, sometimes highly mixed with clay and of uniform and compact structure, and at others including more or less angular fragments, giving it the appearance of a conglomerate or breccia with a clay matrix, is known in Mexico as *Caliche.* It is found at times forming beds along the sides of limestone and volcanic mountains, and at others as surface-beds in the valleys and lowlands, overlying

beds of marls or calcareous sands and marls. It is also found forming intercalations and filling seams in these rocks, just as gypsum does in gypsiferous marls.

The volcanic tuffs, known in Mexico as *Tepetate* and much valued as a building stone, are also referred to this period.

The statements of Aguilera regarding these deposits are so full, and cover the ground so well, that although we observed the deposits in many places during the trip there is little to be added in the way of details.

It may be suggested, however, that all of the *Caliche* may not be of this age. I think that some of the deposits of this material observed between Zubiate and Hermosillo and around Torres may prove to belong to the Tertiary, as is the case with similar materials in southwest Texas, where it underlies the Equus beds. The same statement may, and probably will, hold good in regard to the *Tepetate.*

We may note, however, the occurrence of shell reefs observed along the first stage of our trip. The level country lying between the coast and Batamotal is dotted here and there with numerous shell reefs which contain quantities of shells of about the same species as those now living along the present coast. These shells extend inland to within ten miles of Ortiz, and we found them at and beyond the Chiltopena ranch to the east. At this point the plain is interrupted by hills of eruptive materials, and the reefs are found at various elevations along the flanks of these hills. In these reefs the specimens taken from the higher elevations seem to be finer and of larger growth than those of the lower levels, as if the earlier conditions were more favorable to their development than the later ones.

Tertiary.

Our investigations show a much more extended section of the Tertiary deposits than has previously been recognized here; and while their assignment to this period rests purely on stratigraphic grounds, since no fossiliferous beds have so far been observed, it seems to us clearly warranted by the facts. We have observed what we consider to be the basal beds of these deposits resting unconformably upon fossiliferous Cretaceous

rocks, and have found deposits of Pleistocene age resting upon the eroded surface of beds which we here put in the Pliocene.

Of the three divisions here suggested, the two older are composed of eruptives and sedimentary rocks, interbedded without apparent erosion between successive strata.

At the beginning of our trip we only recognized one formation—the Lista Blanca—of anything resembling this character of deposits; and the others were gradually differentiated during the trip. It is possible, therefore, that some of the earlier references of deposits to the Lista Blanca may prove erroneous, as such beds of Nogales material as we may have passed there would naturally have been so classed. The same is true as regards some of the beds of the Baucari and Nogales, for, although it was thought during a good part of the trip that there were two series of deposits, absolute proof of the fact was lacking until just before the end of the trip. There are many points of resemblance between the beds of the Lista Blanca and the eruptives of the Nogales, and it is sometimes difficult to determine whether beds of conglomerate belong to one or the other of these deposits.

In a region such as this, where successive volcanic extravasations and re-distributions seem to have occurred in different geologic epochs, the materials of which possess considerable similarity in themselves and have been subjected to somewhat similar conditions of metamorphism, I think it will be found absolutely necessary to settle the age of the different eruptives in the field by their stratigraphic succession, where it is possible to do so, and that much detail-work of this kind will have to be done before all of the facts are finally differentiated and a firm basis is laid for the petrographic work which is essential to a full understanding of them.

The three divisions proposed for the deposits thus referred to the Tertiary are here named, for purposes of description, from the locality of the determination of each and in descending order:

The Baucari Division;
The Nogales Division;
The Trincheras Division.

The Baucari Division.—This name is here used for a series of sands, clayey sands and conglomerates of considerable thick-

ness and of extremely even bedding. It appears to be, most probably, a lacustrine deposit laid down in very quiet waters, although some of the rocks in the conglomerate have diameters of 8 to 12 inches. This size is unusual, however; for the most part they are considerably smaller, and more or less rounded. The pebbles consist of fragments of both volcanic and sedimentary rocks, and the matrix is always siliceous, although at times it may contain clay in greater or less proportion. At two or three points only were the beds predominatingly clayey. The beds are all of light colors—gray or pink, usually—and are only of moderate hardness, not approaching, in this regard, the Nogales or older deposits.

The beds are usually horizontal or only slightly inclined, and the lines of stratification are very prominent and straight. Flexing was only seen in the immediate vicinity of some intruding rock, and cross-bedding was rarely observed in the beds herein referred to this division.

It is found in contact with various beds of the earlier formations, from the granites of supposed Archean age to the Nogales beds of the Tertiary, and it is overlain, so far as we have found, only by beds of the Pleistocene.

The various beds of the division are well developed in the vicinity of the town of Baucari, on the Cedros river, and northward as far as we went along the valley of that stream. Indeed, the division, as a whole, seems directly connected with the different drainage-areas in which it was observed, as though it might have resulted from lakes formerly occupying the basins through which the present streams have since cut their way.

At Baucari the contact is directly with the granite. Here the base is a breccia of granitic material, growing finer and finer as we rise in the beds, until it becomes an arkose, with only an occasional small fragment of granite. This is succeeded by thinly-bedded sandy clays of light-brown color, which also carry a few fragments of granite; but at a distance from the granite the beds are of still more sandy character, thinly and evenly bedded. The beds at this point are 100 feet in thickness.

Directly on the creek bank only the sandy beds are exposed, but away from it the beds are more clayey, and weather to a black, waxy soil.

At Bacusa ranch, 3 miles south of Quiriego, the bluff shows 40 feet of the conglomerate, and the banks of the Cedros north of Quiriego show these beds with a thickness of several hundred feet. Here they dip westerly, at an angle of 15°. The basal portion here, as at Baucari, is a breccia resting on the granite and Triassic rocks, and the upper portion is composed of sands and clayey sand with few pebbles. The principal characteristics, as shown here, are the general sandy and conglomeritic nature and the extremely even bedding of the deposits.

These gently-inclined beds give character to the topography of the Cedros valley, wherein they form the mesas, or low, flat-topped hills. A section made across the valley of the Cedros, just south of Quiriego, shows that at this point the Baucari formation occupies the entire valley lying in the trough of a synclinal of Triassic rocks.

Deposits of this formation were also observed near Baroyeca, and resting unconformably on the Nogales beds east of Tonichi.

The Nogales Division.—In the vicinity of the Cienega ranch, east of San Pedro, we found a series of beds differing from those described as Baucari, and underlying them unconformably. These beds are composed of rhyolitic lavas, agglomerates, etc., beds of conglomerate, and some andesitic lavas and tuffs. The rhyolite varies in texture from granitoid to glassy; and in the agglomerates the matrix is often kaolinized, and at times carries considerable quartz. The tuffs are very massive in most places, and pass into agglomerates at times. The included fragments are usually more angular than in some of the other beds of similar character which we found. The conglomerates are more massive than those of the Baucari, although they resemble the latter at times. The enclosed pebbles are more variable in size, the lines of stratification are not so straight or even, and cross-bedding was observed at several places. The beds are also much more highly indurated than is usual with the Baucari, and they form many very sharp and craggy peaks between Nogales and San Pedro.

The deposits around Nogales comprise granitoid and porphyritic rhyolites overlain by a rhyolitic tuff and agglomerate of considerable thickness. The granitic rock shows intersect-

ing and included masses of a more basic rock, which varies in color from gray to greenish-gray and brown. The tuff or agglomerate appears bedded and, more rarely, massive; but nowhere does it present quite the evenly-bedded appearance of the Baucari. The matrix is almost entirely feldspathic and partially kaolinized, and the included pebbles and boulders are largely of rhyolite and almost entirely of late volcanic rocks. Few of the fragments are rounded; and there is usually a small amount of quartz present, either in matrix or inclusions. The formation also carries, in this vicinity, a band of limestone.

Along our northern route these beds were seen principally in detached outcrops, so that only a very generalized section could be made.

The base of these deposits, which was seen west of San Pedro, appeared to be a heavy conglomerate or breccia, followed by beds of andesitic lavas and tuff. Above these there is, near the ranch-house, a heavy conglomerate (or, probably, an agglomerate) of rhyolitic materials. Its color is brown, the included pebbles and boulders are apparently all of eruptive origin (principally rhyolite), and the matrix is a kaolinized material. This bed is covered here by a flow of rhyolite. The thickness of the total section cannot be less than 1000 feet.

The mountains forming the divide between the Santa Cruz and San Pedro, just north of Santa Cruz, give many good exposures of the Nogales. The porphyry exposed along the bank of the Santa Cruz is covered in places by a volcanic conglomerate, and the whole descent into the San Pedro valley is over the agglomerate tuffs, breccias, etc., of the Nogales.

While the contact of these beds with those of the Trincheras division was not observed at any point, the dip of the beds and their geographical location would put them naturally where I have placed them.

Just before reaching the Yaqui river at Buena Vista the Nogales conglomerates were found resting on the base of a hill composed of Lista Blanca rocks.

At Buena Vista, comparatively only a small amount of the Nogales is exposed, by far the greater amount of the conglomerate which here forms the bank of the river belonging, as nearly as we could determine, to the Lista Blanca. The dif-

ference between the two conglomerates as seen here is that the Nogales is, as usual, quartzose, while the Lista Blanca is entirely feldspathic, partially kaolinized.

On the Pilares ranch, east of Tonichi, there is another excellent exposure of the Nogales beds. The pillar which gives its name to the ranch is composed of the conglomerate belonging to these beds. It sits in a saddle of the mountain; its southern face, which is vertical, is at least 300 feet high, and the nearly horizontal stratification-planes are very distinct. The boulders and pebbles include fragments of Triassic eruptives and quartzites, scoriaceous lava, etc., and the matrix is feldspathic, with a considerable amount of quartz sand. The pebbles are considerably rounded, and at the base some of them are very large. The formation is here quite evenly bedded, and rests upon a bed of volcanic tuff.

At Aguas Calientes, between Tonichi and Pilares, the Nogales is again found, resting upon the tuff; and from this point to Tonichi these beds are seen in the banks of the creek which constitutes the road. Half a mile below Aguas Calientes we have the proof of the pre-Pliocene age of the Nogales, which shows at this point considerable erosion and forms a number of low hills, cut through by the later erosion of the creek. Immediately behind these rise other elevations of thinly-stratified loams of the Baucari division, with a dip differing considerably from that of the underlying Nogales, and overlain in turn by the uncompacted gravels of the Pleistocene. Continuing down the creek, the non-conformity between these Baucari loams and overlying gravels and the Nogales becomes even more marked.

Tonichi is located on the Nogales conglomerate, and the valley of the Yaqui, south and west of the town, shows the greatest development of the conglomeritic beds observed during the entire trip. As exposed along the river, they rest upon a brownish-black lava, which overlies a white tuff or ash, similar to that seen at Pilares and Aguas Calientes. Down the river they appear to form hills 200 feet or more in height; and, as they dip at an angle of about 10° and are exposed for such a distance along the river, the thickness of the formation at this point must be very considerable; but we did not have an opportunity to determine it.

On Casita creek, between Tecoripa and Casita, the Nogales appears with a highly eroded surface, on which is found a deposit from 20 to 30 feet thick of Pleistocene gravels and silts.

The Trincheras Division.—This name is applied to a series of beds comprising a great conglomerate, covered by a complex of andesitic lavas and sandstones, the outcrops of which were observed from a point three miles west of La Morita, westward, nearly to San Pedro. While the total thickness of the beds here classed in this division is more than 2000 feet, it does not include the entire series, a part of the basal rocks being unknown, and its contact with the Nogales not having been found. The reference of it to the Tertiary is based solely on its stratigraphic position and petrographic character, since no fossiliferous beds whatever were found in the exposures studied.

The best section observed was at the Trincheras, where the creek had uncovered the beds for a mile or more, leaving only two or three places so covered that the rock could not be determined. The beds dip 45° to the southwest, and the carefully-measured section is as follows:

Trincheras Section.

Beginning at Top.	Feet.
1. Brown and purple lavas,	183
2. Gray lava,	73
3. Light-gray ash or tuff,	15
4. Gray rhyolite, weathering into a scoriaceous mass,	7
5. Dark-gray lava,	8
6. Covered,	110
7. Purple sandstone, weathering brown,	36
8. Fine-grained gray sandstone,	28
9. Purple sandstone, weathering brown,	15
10. Thin-bedded purple lavas (?),	33
11. Purple sandstone, weathering brown,	7
12. Thin-bedded purple lavas (?), mottled and weathering white,	14
13. Purple sands, weathering brown,	30
14. Shaly sandstone, cross-bedded and ripple-marked, with worm-borings,	44
15. Grit,	8
16. Covered,	7
17. Spotted sandstone,	22
18. Brown sandstone,	28
19. Covered,	30
20. Brown calcareous sandstone,	36
21. Thin-bedded sandstone,	55

Beginning at Top.	Feet.
22. Spotted sandstone,	11
23. Covered,	67
24. Calcareous sandstone,	34
25. Calcareous sandstone, thin-bedded,	22
26. Calcareous sandstone,	12
27. Spotted sandstone, brown and gray,	200
28. Blue siliceous limestone with flints,	2
29. Gray and brown spotted sandstone,	120
30. Blue siliceous limestone with flints,	10
31. Conglomerate of siliceous pebbles in matrix of lava like 32,	8
32. Thin-bedded brown and purple lavas,	37
33. Conglomerate with lava matrix,	2
34. Brown and purple-bedded lavas,	150
35. Conglomerate of ash and lime,	16
36. Volcanic ash or tuff, cut by porphyritic streaks and bands,	175
37. Trincheras conglomerate. (Base not seen.),	1000
Total,	2655

The Trincheras conglomerate is a bedded deposit of indurated volcanic ash or tuff, holding pebbles or boulders of volcanic rocks, limestones, quartzites, granite, brown lava, marble, flint, etc. The granites are light-colored, like the older granites of the more southern area; the limestones are Cretaceous and older, as shown by the fragments of fossils which they contain; the lavas are Triassic, and the quartzites are dense and glassy—Triassic or older. The entire section differs in character from any other rocks observed on the trip. From the road, the foot-hills of the San José mountains to the north seem to be composed entirely of these beds.

Near La Morita, where the base of the beds was observed, it was a breccia of quartzitic materials, overlying the limestones which are seemingly of Cretaceous age. A little further west, the Trincheras conglomerate is found; but the intervening beds are not seen.

II. Mesozoic.

According to Aguilera, the different sedimentary formations which, taken together, constitute the secondary or Mesozoic group are not all represented in Mexico. Those which are found belong to the latest subdivision or upper beds of the Triassic and Jurassic systems, or to the several divisions of the Cretaceous.

Cretaceous.

Aguilera divides the Cretaceous rocks of Mexico into three series, the Lower, Middle and Upper.

The Lower Cretaceous is composed of argillaceous slates, marly slates, limy clays and marly sands, of greenish color and more or less compact. These alternate in beds of different fineness and hardness, and are covered by clay-slates of variegated colors. The sands are commonly traversed by shrinkage-cracks that subdivide the mass into more or less regular polyhedrons, which are usually rhombic prisms. These are united by a green substance, produced by the alteration of ferro-magnesian elements derived from the pre-existing diorites, hornblendes, granites, etc., giving the deposits a close likeness to the glauconitic green-sand of the *Quadersandstein* of Saxony, Bohemia and Silesia, and the glauconitic chalk of Normandy. In Mexico, however, these beds correspond with the lower green-sands.

The predominating colors of these rocks are: For the clay slates, ashy-gray to grayish-black; for the sandstones with calcareous cement, different shades of gray and yellow, more or less obscure; for the glauconitic sands and slates, green of various shades; and for the upper clay-slates, reddish-gray, bluish-gray, yellowish-gray and green. The order of the superposition of the rocks is as follows:

1. Clay-slates, with more or less carbonate of lime toward the top.
2. Sands, with calcareous cement and calcareous sandstone. At the base these alternate with occasional bands of clay-slate; and toward the top these alternations become much more frequent.
3. Green marly sands of varying degrees of fineness and hardness. These sometimes alternate with the preceding sands.
4. Clay-slates of variegated colors, very variable, sometimes forming deposits of considerable thickness, which mark by beds of marly lime the passage to the limestones, while at other times the passage is direct from the sandstone to the lime-shales, and from these to the compact limestone of the Middle Cretaceous.

The rocks of the Middle Cretaceous are: Compact lime-

stones, usually ashy-gray, blue or black, most frequently occurring in very massive beds, and always accompanied by nodules and bands of flints, distributed parallel to the bedding-planes, forming lines of flat lenses or bands of flint, intercalated in the beds of lime and frequently repeated. The limestone is in many cases magnesian, but rarely a true dolomite. The beds are very rich in fossils, which are usually preserved as calcspar.

These limestones are nearly always fetid. They usually contain a variable proportion of clay, which, when sufficient in amount, gives the beds an imperfect slaty structure.

By the metamorphic action of the igneous rocks this compact limestone has been altered in places to granular limestone and marbles of different grades.

To the Upper Cretaceous, Aguilera referred those formations which had been seen only in the northeastern part of Mexico, and especially in the valley of the Rio Grande. The rocks are sandstones of medium and fine grain, in color gray and reddish-gray, mixed with more or less dirty shades of yellow, and alternating with gray, blackish-gray and black clay-shales. These pass into marl-slates, more or less limy. The sandstones and shales are more or less friable, but sometimes of considerable hardness.

The first rocks belonging, as we think, to this period which we encountered on our trip were found at Cobache mountain, about 9 miles west of Casita. Here we found in the foot-hills a heavy deposit of a very granular light-gray limestone, containing large quantities of cherty material, having a northwest dip and resting upon a pegmatitic granite, which may be (although I do not think it is) a part of the granitoid form of the Triassic Lista Blanca. The cherts are very peculiar in shape, and appear to be simply, in large measure at least, the silicified remains of hippuritid forms and of sponges. The supposed hippuritid forms are very abundant, and were found in all positions; and the numerous sections observed seemed to show the tripartite structure of the shell, and also the shape of the living cavity. They were, however, too indistinct for positive identification. The beds above those contain the sponge-forms just mentioned, which are also very plentiful. A similar association of these forms has been found at Double mountains and

other points in northwest Texas; but at no place have I seen such large individuals as at Cobache. These limestones are unconformable with all underlying rocks. As has been said, they rest upon a granite rock at the north end of the foot-hills. Further south, on the western face of the main mountain, the limestones rest upon the upturned edges of a series of marbles and quartzites, which are provisionally referred to the Cambrian. Along the southern and eastern faces little was seen except the Cretaceous beds, which, in some places, are worn into great caves.

Four miles east of Zubiate there is another exposure of beds of limestone, similar to those described above; but the fossils in these are neither so abundant nor so well preserved. At this point the limestones rest upon a granitic rock, which we proved, by direct stratigraphic work, to be the granitoid form of our Lista Blanca beds.

West of Zubiate the Cretaceous limestones appear in the hills bordering the road to Hermosillo; and at Hermosillo there are hills of granular limestone, which Aguilera refers to the Cretaceous. Although no fossils were found, the rock is very similar to that seen east of it.

By far the best exposure observed, however, is that near Cabullona, northeast of La Morita. Here appears a great series of Cretaceous rocks, probably including strata belonging to both the Lower and Middle divisions of the Mexican geologists, with other beds of which I find no description at all.

A section made about 2 miles from the Cabullona ranch-house gave the following:

1. Interbedded sands and clays of varied colors. The materials are altered in places by metamorphism, some being quartzitic, and some of the clays hardened and greasy. There are some intercalated andesitic beds and dikes of porphyry. The top was not seen, 1000 feet.

2. Massive limestones: light-colored semi-marbles at the top, followed by brown and gray limestone. All the beds are very fossiliferous; but the fossils appear only as cherty protuberances on weathered surfaces, and in many cases are so broken as to be scarcely distinguishable. Among the forms certainly recognized were a small *Gryphæa* and a *Trigonia* (like *T. Emoryi*). The middle beds carry flints in considerable quan-

tities, and the *Gryphæa* occurs in the basal portion in great numbers, 500 feet.

3. A series of interbedded marls and marly limestones, with large numbers of a very heavy oyster, *Trigonia*, *Cardita*, and other forms, 900 feet.

4. Quartzites, sands and interbedded clays or marls; bottom not seen, 400 feet.

Except for their metamorphosed condition, the uppermost beds of this section resemble very closely the "coal-series" of the section made at Eagle Pass, Texas; and, like those beds, they are coal-bearing. They cover quite an extensive area in this region, but are badly cut up and disturbed by eruptive intrusions. These beds comprise alternations of sands and clays with ferruginous concretions (some of which are of large size), considerable quantities of gypsum, and some petrified wood. The sandstones vary from fine-grained to grit, and the clays from thosé nearly pure to those with a large admixture of sand. The metamorphism directly or indirectly due to the volcanic extravasations which accompanied and followed the deposition of these beds has produced, in addition to its indurating effects, bright purple and greenish colors in some places, so that some of the beds closely simulate those of the tuff itself. The beds are somewhat faulted and broken. Our work did not extend far enough to the north to reach the top of the beds, which are certainly more than 1000 feet in thickness. The only fossils found were specimens of a small square-beaked oyster, which occurred just below the coal.

There are two beds of coal, both highly altered. The lower is quite graphitic, and the upper, while retaining the structure of bituminous coal, is an anthracite in its composition.

The massive limestones underlie these sands and clays, and, as far as could be seen, without any unconformability. These limestones seem to correspond very well with Aguilera's description of the Middle Cretaceous. The *Gryphæa* which they carry in such abundance resembles very closely the variety found at the base of the Fredericksburg beds, in northern Coahuila.

Time did not permit a study of the underlying beds, and all the details obtained are given in the above section.

West of the ranch, the west end of the Cabullona mountain showed some other features of the Cretaceous. Here, overlying the granite and granitic Lista Blanca, is a small thickness of quartzites, followed by marly limestones with great numbers of fossils, which look to me like *Washita* forms. At the base, the principal fossils were oysters; but above these many other forms were observed, including *Ammonites*, *Cardita*, *Pectens*, *Trigonia*, etc. Above these there is a bed of oysters and *Exogyra* of large size. The oyster has a square beak like *diluviana*, and the shell is half an inch or more in thickness. The *Exogyra* is very like the *americana* of Marcou. Two specimens were measured, with the following results:

	Centim.	Centim.
Length, ...	15	12.5
Breadth, ...	12	9.4
Thickness, ...	8	5.0

The beds themselves resemble those of No. 3 of the previous section in their lithological composition, but the appearance of the fossils suggests a higher horizon.* The oysters are exceedingly abundant, and places on top of the hills are completely covered with specimens weathered from the marly limestone.

Triassic.

Aguilera says that rocks of the upper part of this system, without occupying very broad areas, crop out at many points. These beds are described as consisting of different kinds of quartzose sandstones and clay-shales, which vary considerably in texture and composition. The sandstones vary in texture from fine-grained to breccias, the structure, being modified with change of texture, becoming more massive with the fineness of the grain. The shales vary from pelitic, that have the appearance of steatite-slates, to less fine-grained kinds that belong to the psammites. The composition of the sandstones and shales also varies with their position. The former range from quartzose sandstones in the lower beds to marly sandstones in the upper, while the composition of the slates ranges

* A few specimens were sent to Mr. T. W. Stanton, of the United States National Museum, who writes me that they are most probably Fredericksburg forms.

from pure clay at the base to marly clay and marl in the upper portions; while the enclosed scales of mica gradually increase until they pass into the true psammites, the change of grain giving them the appearance of sandstones. Finally, the increasing proportion of carbonate of lime terminates the series with marl-shales high in lime, above which are deposited, at certain localities, true lime-shales, more or less mixed with clay. .

These changes of composition and texture show themselves as much in the horizontal extension of the beds as in the vertical, with the difference that they are always more gradual in the horizontal direction. Thus, the same bed, followed for a long distance, may show all the variations mentioned, changing from true conglomerate of small or medium grain to sandstones of various degrees of fineness, which, passing through psammites, end in clay-slates.

The hardness of these rocks varies, in accordance with their composition and the influence of the eruption of igneous rocks, from that of hard quartzitic sandstone to that of very friable sandstone. The slates also show notable variations of this kind, changing from more or less perfect fissile slates and shales to slates of very imperfect cleavage.

The color of the sandstones varies from a gray, more or less clear, to different shades of red and yellow; and that of the shales from ashy-gray to grayish-black in the lower and middle portions of the complex, and in the upper portion from black of different shades to variegated and irregular tints which imitate perfectly the colors of the *Marnes irisées* of the Keuper.

No beds of marine Triassic have been recognized.*

In places the rocks occupy the upper portion of low hills, resting upon the crystalline slates or granites, pegmatites, etc., without any covering of more recent sedimentary rocks; elsewhere, especially at Sierra de Acatlán and around Tezoatlán, they are intercalated between the Huronian slates and the marly sands and slates of the upper Jurassic; and, finally, there are localities in which the Triassic rocks are covered, some-

* Aguilera probably overlooked the determination of fossils from San Marcial and the description of *Panopea remondi* (Meek) from that locality, in the *Paleontology of California*, vol. i., p. 28.

times by the lower beds of the Cretaceous, and sometimes by Tertiary sediments.

The fossils contained in these rocks, although very abundant, have been very little studied. With the exception of the work of Prof. J. S. Newberry on some of the fossil plants of Los Bronces in Sonora, there has been little or no study of the flora of the terrane. The following list includes the species described by Dr. Newberry, and some others collected at different localities:

Mertensides bullatus (Bumbury); *Asterotheca whitneyi* (Newberry); *A. virginiensis* (Fontaine); *Asplenium* (*Cladophlebis*) *mexicanum* (Newberry); *Lacopteris emmonsi* (Fontaine); *L. af. münsteri* (Schenk); *Adriania af. baruthina* (Bru.); *Macroptæniopteris elegans* (Newberry); *M. magnifolia* (Newberry); *Gangamopteris americanus* (Newberry); *Camptopteris remondi* (Newberry); *Equisetum af. münsteri*, *Podozamites ? crassifolia* (Newberry); *Zamites occidentalis* (Newberry); *Otozamites macombi* (Newberry); *Ctenophyllum emmonsi* (Newberry); *Dionites af. rigidus* (Andr.); *Pterophyllum delicatulum* (Newberry); *P. fragile* (Newberry); *P. robustum* (Newberry, not Emmons); *Nilsonia polymorpha* (Schenk); *Sphenozamites rogersianus* (Fontaine); *Baiera radiata* (Newberry); *Palisaya af. carolinensis* (Fontaine).

No mention whatever is made of any molluscan remains.

The rocks which I consider referable to this period comprise not only the considerable thickness of sedimentaries included in the above description, but also a complex of eruptives, which is largely andesitic in character.

The ordinary sedimentary deposits, consisting of sandstones and clays, with beds of coal and graphite, are here called the Barranca beds, from the locality at which we found their best development, while the eruptives have been called the Lista Blanca division, from the mountain in which they were first observed.

The Barranca Division.—The lowest member of this series seems to have been a series of sandstones, but it is not always present, and the basal rocks are often one or the other of the overlying beds. Indeed, at times, the upper conglomerate, resting directly on the older rocks, is the only member present. Some of the apparent variations may be due to the variable character of the beds themselves, as described by Aguilera.

The second member, as we observed it, is a series of interbedded shales, slates and sands, with beds of graphite and coal.

The third is a massive sandstone, with pyrites, which often segregate in patches and show strong colorings of iron and copper.

The upper bed is a conglomerate or breccia of sandstone, with a siliceous matrix which is almost always so strongly altered as to be of the nature of a quartzite. This is seemingly unconformable with the other beds.

The great body of sandstones and clays has been strongly metamorphosed, and is now, for the most part, beds of slate and quartzite. These form the surface-rocks over the greater part of the area between the Yaqui river and the Matape; and in the ranges just west of the Sierra Madre proper they are again and again seen at the surface. They are usually much tilted and broken.

Around Baroyeca the Barranca beds are exposed in many places, standing almost on edge and highly metamorphosed. The degree of metamorphism differs with the locality; at places the clays were slates, and the granular quartzite was so changed as to have almost the appearance of a white quartz. They were faulted as well as tilted, and we were unable to get a satisfactory section. The bands of red quartzite are looked upon by the people of the vicinity as great ore-veins, and prospecting has been carried on in them at many places. The Barranca beds rest directly upon the granite, and are overlain by the Lista Blanca.

At the Cerro Colorado the Barranca beds are exposed in a thickness of several hundred feet. They dip at a high angle, and strike N. 30° W. by compass. The rock is principally the upper quartzitic conglomerate, and is impregnated in places with copper and other minerals.

In the mountains south of Baroyeca there are also exposures of the quartzite and quartzite conglomerate. The strike is, as before, N. 30° W., and the dip about 30° S. The quartzite carries large amounts of iron pyrites, and in places is strongly stained with copper carbonates; but these places are of limited extent. A little galena and magnetite were also found in it.

These quartzites were found again north of Suaqui Grande,

capped by Lista Blanca; and in a synclinal valley north of Gaudalupe we found both quartzites and slates.

The more detailed observations of these beds were made in the Barranca district, where the exposures are very considerable; but, on account of the faulting, the exact relations of the different parts of the section were not entirely clear.

The trail between Lo de Campo and San Xavier shows following succession of beds:

Section No. 1.

1. Coarse granitic sandstone.
2. Slate.
3. Granitic sandstone, finer grained than No. 1.
4. Siliceous slate.
5. Bluish sandstone.
6. Fine-grained siliceous slate.
7. Granitic sand.
8. Shales with brown leaves.
9. White sandstone.
10. Ferruginous clay.
11. Sandstone.
12. Slate.
13. Sandstone.

Fault-line, E.–W. (magnetic).

Section No. 2.

1. Shales.
2. Covered.
3. Brown slate.
4. Blue shale.
5. Slate with leaf impressions.
6. Gray micaceous sandstone.
7. Clay-shales, ferruginous, weathering in nodular forms and containing leaf-impressions.
8. Sandstone.
9. Slate.
10. Yellow sandstone.

Section No. 3.

1. Slate.
2. Coarse sandstone.
3. Slate.

4. Coarse granitic sandstone, with feldspar grains, kaolinized, and some gravel.
5. Blue shale and slate.
6. Granitic sands.
7. Slates.

As nearly as I could place them, Section 3 seems to overlie Section 2, and this in turn overlies Section 1.

Between San Xavier and Atalanta we found the following:

Section No. 4.

1. Arenaceous slate, 100 feet.
2. Slate, 75 feet.
3. Drift-covered, 300 feet.
4. Coal-shale, 200 feet.
5. Slates, 40 feet.
6. Shale, 40 feet.
7. Drift-covered, 150 feet.
8. Steely quartzite, 100 feet.
9. Quartzite with coal-seam, 150 feet.
10. Quartz conglomerate, 15 feet.
11. Quartzite, 30 feet.
12. Slate, 6 feet.
13. Quartzite, 100 feet.
14. Slate, 30 feet.
15. Quartzitic breccia of crushed quartz, 40 feet.
16. Sandstone, 150 feet.
17. Massive quartzite with carbonaceous band, 75 feet.
18. Granite.

Beyond this we passed through massive quartzites, which overlie the coal-slates, and are in turn overlain by other rocks of the series.

Taken altogether, there must be at least 4000 feet of these sedimentary rocks. In the Barranca district no limestones whatever were observed.

In the vicinity of San Marcial the rocks include highly graphitic quartzites or indurated sandstones, heavy beds of impure graphite, clays with leaf-impressions, and others with many casts of molluscan fossils.*

* These include *Panopea remondi* (Meek), referred to in foot-note, p. 138, and several other forms not yet determined.

Towards the top of the series the beds become more limy, and bands of clayey limestone are found. These beds are overlain here by the pyroxenic andesites of the Lista Blanca.

The Lista Blanca Division.—The volcanic complex embraced under this name consists of a series of andesitic lavas, agglomerates and tuffs, which are found resting directly upon the beds of the Barranca division, in many places, and underlying the Cretaceous deposits.

In texture, these rocks vary from glassy to granitoid, the porphyritic being highly developed in many beds. Various shades of purple, green and gray are common, and the upper lava is usually of a brownish-black color, which accentuates the bed of whitish tuff or ash on which it rests, and which gives its name to the mountain and the beds. There is also a band of bright red, which is present at many localities.

The distribution of these beds is greater than that of the Barranca division, as they are found resting upon the older rocks in places where the earlier beds of this system are missing.

The basal beds appear to be conglomerate and sandstone, with interstratified tuffs and lavas. These are followed by an agglomerate of considerable thickness; and this by tuffs, and finally by a heavy bed of dark-brown lava, which marks the culmination of the division. Lava-flows are found at intervals throughout the series, and the beds are also cut by numerous dikes of porphyritic and other eruptive materials. The numerous cracks traversing these beds are filled with calcspar, carrying more or less iron.

Lista Blanca mountain, from which the formation here described takes its name, is a few miles southwest of the town of San Marcial, and is plainly distinguishable from Ortiz by a prominent point that juts out from its face. The section of the Lista Blanca rocks, as shown in this mountain, is as follows:

1. Andesitic flow, at the base of which is a black lava almost glassy in texture, 50 feet.
2. Tuff, 30 feet.
3. Brown vesicular lava; the cavities filled with secondary quartz, 30 feet.
4. Agglomeritic and slaty andesite, 50 feet.

5. Tuff; the base tufaceous agglomerate shading up into true tuff, 100 feet.

6. Andesitic agglomerate, 30 feet.

7. Volcanic conglomerate of andesitic pebbles in purple-brown matrix, with lenses of tuff. This seems to rest upon the upper quartzites of the Barranca beds, 75 feet.

In the upper andesitic flow, No. 1, there is a great spheroidal structure shown, the spheroid having a diameter of not less than 40 feet, and being very perfectly outlined in the face of the bluff.

No. 5 is the Lista Blanca band proper. The upper portion here shows considerable agatized material.

No. 7 includes boulders of andesitic agglomerates, porphyritic andesites, hornblende-andesites, gray vesicular lava and Triassic slate. The beds of tuff are more numerous toward the top. The rock-inclusions are mostly angular, but some are rounded. The base was not seen, but this bed has probably a thickness of 200 feet at this place.

At the crossing of the Mayo river, not far from Aguas Calientes, a good exposure of the lower beds of the Lista Blanca was observed. They comprise stratified tuffs and some sandstones. At one point on the bank these beds were turned on edge; but this proved to be merely a local condition, for elsewhere the exposures showed only a moderate westerly dip.

From Aguas Calientes to Sobia the country-rock is Lista Blanca, with a single exposure of quartzite gravel and conglomerate, which belongs, most probably, to the upper beds of the Barranca division. North of Sobia the exposures are also of the rocks of the lower division of the Lista Blanca. A range of hills is composed of a series of tuffs and agglomerates, cut by porphyritic intrusions.

In the vicinity of Baucari, the Lista Blanca lies directly on the granite, the agglomerates looking like those of the Middle Division.

On the trip eastward from Quiriego, by way of Trigo, into the higher mountains, we found a great development of volcanic rocks, a part of which belong to the Lista Blanca, while others are of later date and more nearly like those of Mazatlan. These beds, which may belong to the Nogales, have the appearance of a consolidated tuff, carrying only small and sharp-cor-

nered fragments of porphyritic materials, similar to itself, and succeeded by stratified tuffs, and then by other massive and brecciated beds. All are of lighter color than is usual in the Lista Blanca, and, while apparently quite compact, are really rather friable. The lower bed of consolidated tuff is much more massive than I have seen it elsewhere.

Among the beds more certainly of Lista Blanca character, we noted one, full of spherulitic masses, which weathered out as balls, and were quite numerous on the hill-side. Some of the lava-beds contain considerable quantities of agate, while others carry a white stellated crystalline mineral. These deposits are certainly more than 1000 feet in thickness.

Between Quiriego and Cedros the Lista Blanca was seen at many places, and around Cedros it is well developed, and is capped in places by beds which I now think belong to the Nogales, although at the time of our visit they were referred to the Lista Blanca. The beds exposed here have a thickness of over 2000 feet.

Just in the edge of Cedros we find the exposure of the bed of white tuff, with its band of red and the brown lava which elsewhere forms the top of the Lista. Above the lava are heavy deposits of lighter-colored eruptives, but whether they are conformable or not with those below could not be determined, because no clear contact was seen.

Between Batacosa and Baroyeca a contact was observed between the granite and the Lista Blanca. The granite was highly decomposed and similar to that observed at the contact near Baucari. The base of the volcanic rock contained many fragments of the granite. The basal conglomerate is here 12 feet thick, and is covered by a bed of tuff 3 feet in thickness, and this by a series of beds of tuff, thin-bedded or shaly, interstratified with bands of granite-sand 2 to 3 inches thick.

In the hills south of Baroyeca the Lista Blanca is the predominating rock, and is underlain by granite in some places, and by the Barranca beds in others. The same is true of the region between Baroyeca and Buena Vista, and beyond that point to Lo de Campo.

At Lo de Campo the contact of the Lista Blanca with the upper quartzite conglomerate of the Barranca series is well shown in the bank of the creek. The basal bed of the Lista is

composed of pebbles and boulders of the underlying material, both angular and rounded, in a siliceous matrix. This is not more than 4 feet thick, and is overlain by a bed of lava, which is followed by a bed of tuff. The hills west of this point show practically the same section as that of the Lista Blanca mountain all of the members being present in the same order. The thickness, however, is much greater than at the type-locality.

Between Lo de Campo and the pass west of Barranca, the basal agglomerate of the Lista is the principal rock in sight. It is a volcanic breccia of purple and yellow or greenish materials, more or less porphyritic, in a purple ground-mass, with interbedded bands of purple andesitic lavas. These beds, in places, are traversed by numerous cracks filled with calcite and more or less colored with iron. They are succeeded by brown basaltic lavas.

The Lista Blanca rocks are also well shown along Calera creek, between Barranca and the Yaqui river, including what seems to be practically the entire series, from the basal agglomerates to the andesites capping the Lista band.

At Pilares the Lista Blanca is found between the Barranca beds and the beds of probable equivalency to those at Nogales. Here, for the first time, we noticed its granitoid texture. At places it so closely simulates a light pink granite that it would ordinarily be so classed. We were able to trace the felsitic and porphyritic beds directly into the granitic ones, and found places in the latter in which the forms of the inclusions in the agglomerate could still be distinguished by difference of shade, which became quite marked on wetting the specimens. This Lista Blanca is the only pink granite which we found; and thereafter, when a pink granite was observed, it was almost always possible to trace it into the Lista agglomerate.

Numerous exposures of Lista Blanca were observed between Lo de Campo and Zubiate. About three miles west of the former locality the Lista is cut by a dike of phonolite. Four miles east of Zubiate, in its granitoid form, it underlies beds of the Cretaceous, and overlies those provisionally referred to the Silurian.

In the Cabullona mountains, its relation to the Cretaceous is also well shown. The beds here have a thickness approximating 1000 feet. The conglomerate, with bedded lavas and tuff,

is followed by a small thickness of agglomerate; and above this there is a series of thin-bedded tuffs and lavas, followed by the granitoid agglomerate, and this by a brown lava. It is clearly evident from the exposures here that this complex was extravasated and deposited, and subjected to disturbance and erosion, prior to the deposition of the sediments of the Cretaceous; for I found the quartzites of the Cretaceous resting upon several different horizons of the Lista Blanca. The rocks underlying the Lista at this locality were not clearly made out, but seem to belong to the older granites.

From the field-examination it seems to me that the rocks of the Lista Blanca differ from similar rocks of later age, in that they are usually more basic, and in weathered specimens show little or no quartz. They are also generally more highly indurated than those of later date, and, on the whole, darker in color. The agglomerate contains little or no extraneous matter, consisting seemingly simply of broken crusts of one flow, engulfed in those which succeeded. In the agglomerated tuffs, also, the fragments are almost entirely of a porphyritic character. The rocks of the Lista Blanca seem to be largely andesitic, with a little rhyolite near the top, while the later deposits seem to have a comparatively small amount of the more basic rocks at the base, and to be predominantly rhyolitic.

It is entirely possible that these eruptives may represent a period of time later than the Triassic, and may be of Jurassic age; but the impression made on us in the field was very strong that they and the underlying Triassic beds were part of one system.

III. Paleozoic.

Aguilera says of the Paleozoic deposits that those terranes which form the Paleozoic group have slight representation in this country, and those of which we possess characteristic fossils, which leave no doubt as to their age, belong to the Carboniferous period. There is no place known in the Republic where the Silurian crops out, although there are fossils characteristic of the terrane in the paleontological collections which are authentically of Mexican derivation.

A goniatite belonging to the middle Devonian, and said to have been collected at La Calera, in the mountainous country at Acapulco, caused the organization of parties to search for beds of that age in that vicinity; but, although a heavy bed of

slates was found underlying the Jurassic, its age could not be determined for want of fossils.

The existence of beds of Carboniferous age in Mexico is, however, a demonstrated fact. Rock of this age has been found along the boundary between Mexico and Guatemala. Mr. Prospero Goyzulta, the engineer of the Commission appointed to survey the boundary between these two countries, brought to Mexico two specimens of a compact ashy-gray limestone, which contained specimens belonging to the genus *Productus*. These, although somewhat damaged and incomplete, were identifiable as belonging to the species *semireticulatus*, which is characteristic of the Carboniferous limestone.

The Carboniferous rocks of Mexico are limestones and dolomites, which, according to the investigations of Mr. Saper, "rest in concordant stratification on the Santa Rosa beds, composed of sandy conglomerates and slates of red color," which Mr. Saper refers to Carboniferous or Devonian.

Very few fossils have been obtained from the Carboniferous of Chiapas; and the best preserved, which came from the ranches of La Nueva, La Vainilla, Las Tres Cruces and Palo Amarillo, are:

Fusulina [illegible] (Roem).
Fenestella sp.
Productus semireticulatus (Morton).
Pleurotomaria sp.

Silurian.

The first rocks which we now consider to belong to the Silurian were found in the vicinity of the old Trigo mine. This old and abandoned Spanish mine is on the western slope of the mountains between the Cedros and Mayo rivers, about northeast of Baucari. The rocks are interbedded quartzites and limestones. The limestones are fossiliferous, one bed being largely made up of small encrinite stems. A few brachiopods were seen, with numbers of cup-corals and a few indistinguishable forms. The limestones are semi-crystalline, gray to reddish-gray in color, and usually siliceous. The fossils are badly preserved. No estimate could be made of the thickness of the beds, or of their relation to other rocks in the vicinity.

Two miles northeast of Casita we found a range of hills trending nearly east and west. The western end of these hills

was composed of a massive limestone, weathering dark blue to gray. It is very cherty, with many fossils weathered out on its surface. These comprise cup-corals, mass-corals, branch-corals and encrinite-stems, with a few indeterminate forms. The surface is highly corroded and the rock is full of cylindrical holes, from a half-inch to three feet in diameter, descending at various angles. On the top of the hill these holes occupy fully one-half of the area of outcrop.

These massive limestones are underlain by brown and yellow limestone, apparently somewhat clayey, and resting upon a series of interbedded lime-bands and breccias. The basal bed of the formation at this point is a conglomerate of siliceous pebbles, and this rests with marked unconformity on the un-[illegible] Cambrian. The entire thickness of the Silurian observed at this locality is about 200 feet.

Another point at which rock of similar age was identified is in the pass at the southeast point of the Cobachi mountain, where it lies between the Cambrian rocks that form the base of the eastern face of that mountain and the Triassic quartzites that make up the hills to the east.

It was found again 4 miles east of Zubiate, in the same relations to the Cambrian and the Triassic, and involved with them in a northwest-southeast uplift. At this point we also found it fossiliferous.

On both sides of the road, from this point toward Hermosillo, there are chains of hills and ranges in which it is very probable that other exposures of these rocks will be found when examination is made.

The fossils which were obtained were submitted to Dr. Chas. Schuchert, of the United States National Museum. He sums up the results of his investigation as follows:

"The red weathering limestone found at the Trigo mine, while full of crinoid fragments, mainly segments of columns, has nothing to indicate its age beyond that it may be Silurian, Devonian or Carboniferous.

"The fossils from near Casita may be either Silurian or Devonian. The two genera of corals, *Cyathophyllum* and *Heliolites*, occur in both systems, and are therefore not diagnostic for limited time-determinations. In America, *Heliolites* is unknown beyond the Silurian, but it also occurs in the upper half of the

Ordovician—generally it is regarded as indicative of Silurian. I shall not be surprised, when you secure other material, to learn that the horizon is in the Silurian."

In the field I was inclined to refer these beds to the Carboniferous on account of what seemed to be a few specimens of *Fusulina* in the rocks. Dr. Schuchert, however, found that these were not *Fusulina*; and I therefore place the beds in the Silurian, as indicated by the fossils.

Cambrian.

The rocks referred provisionally to this period comprise a series of marbles, semi-marbles and quartzites, which are shown by their stratigraphic relation to be older than the rocks above referred to the Silurian. No fossils have as yet been found in them, and they are simply placed here until more definite information concerning their age can be obtained.

The first exposure observed was on the lower Cedros between Aguas Calientes and Sobia. Here the high hills on the east bank of the river exhibit a series of interbedded black shales, granular limestones and quartzites, the lithological characters of which are entirely different from those previously described or seen on this trip. They here underlie the Lista Blanca.

At Guamochil, 15 miles east of Tonichi, there is another exposure of these rocks, showing a granular limestone, very coarse-grained and cherty, followed by banded limy slates, showing banding in black and white. It is possible that these slates were originally a very limy clay, as they now show many calcite crystals. The more massive portions contain considerable quantities of iron pyrites of a rich bronze color. These calcareous rocks are connected with a series of quartzites, more glassy in appearance and less granular than those of the Trias; and the entire series shows a high degree of metamorphism. These beds stand at a high angle with a northwest-southeast trend, and are overlain unconformably by the Triassic beds. The disturbances here have been so great that in our limited time no very close estimate could be made of the thickness of the beds; but it must be very considerable, and may reach 3000 feet. No basal contact was found.

Another considerable exposure of these rocks is found in the mountains between Los Bronces and Soyopa, where they stand nearly on edge and have the same strike as before.

Two miles northeast of Casita they were found forming the hills east of those described herein as being composed of Silurian limestone. Here, also, they stand at a high angle, and the basal Silurian conglomerate rests upon their upturned edges.

At Cobachi mountain the eastern face is a bluff some hundreds of feet high, and composed of these banded quartzites, marbles, etc., standing at a very high angle with the Cretaceous beds, having a comparatively gentle dip toward the west, resting upon their strongly-eroded edges. In the foot-hills southeast of this place the Silurian rocks succeed the Cambrian, but the contact was not observed.

Four miles east of Zubiate the banded shales, quartzites and limestones again appear with their northwest-southeast strike, and are overlain by the Silurian, and this, in turn, by the Triassic Lista Blanca, with its granitoid agglomerate, on which the Cretaceous was laid down.

Archæan.

About five leagues northwest of Alamos there are some hills composed of a mica-schist, with occasional bands of harder and more quartzose material. In these harder bands are strong copper colorings, and these, in places, become lenticular streaks several feet in length. Some prospecting-work has been done on these streaks, although there is little in their character to warrant it.

This mica-schist is probably of Archæan age. Besides it, we saw only a few granites which we could refer to this age. The areas covered by these granites and pegmatites is very considerable, and they are chiefly noticeable for their extremely coarse grain and light color.

ECONOMICS.

Without attempting, in this paper, any detailed account of the various mineral deposits of this region, it may be well to note very briefly some of the observed facts which illustrate the connection between the geology and the conditions favorable for ore-deposits.

Prof. Whitney, in his report on the geology of California, calls attention to the Triassic beds as gold-bearing. We find this especially true in Sonora, and believe that most of the pre-

cious metals of that portion of the State examined by us will be found in connection with the Triassic rocks, and more especially with the Lista Blanca or eruptive series of the system.

Contacts of these eruptives with the limestones—whether the limestones underlie them, are cut by them, or are superimposed upon them—are usually ore-bearing. Some very good mines exist elsewhere, also, on this character of contact, of which those of the Sierra Mojada are perhaps the best known. These mines, Mr. Owen informs me, are on the contact of the Lista Blanca and the Cretaceous limestone which overlies it.

Where these and later eruptives come up through the older granites, or through the Barranca beds of the Triassic, they are often accompanied by ore-deposits. Subsequent faulting has, however, made many of the deposits in the Barranca series, although very rich in places, rather uncertain bases for profitable mining.

In some places, where the later eruptives have come up through the Lista Blanca, they have given rise to ore-deposits; but these are not as common as those previously mentioned.

As nearly as we could determine, the principal source of the placer-gold of this region is to be found in the Triassic rocks. Where certain conglomerate-beds of this system cap the hills, the hill-sides show placer gold; where they are missing, the chances are at least unfavorable. It is doubtful, however, whether the parent beds carry sufficient gold to pay for exploitation, but nature's concentration has provided many placers which have repaid, and will still repay, exploitation.

The coal-deposits, both of the Cretaceous and of the Triassic, have been hardly dealt with by volcanic or eruptive forces; and it would seem that the finding of deposits of workable coal of any considerable extent in this area must be the exception, although the vast amounts of graphitic clays and graphite which exist here have excited hopes that good coal would be found in abundance. Most of the coal that has been opened seems rather tender and not very well suited for shipping to any distance. Its anthracitic nature, too, will prevent it being used as generally as a bituminous coal would be. More exploratory work must be done on it before positive statements can be made regarding it.

Notes on the Structure of the Rocky Mountains in the Lewis and Clarke Timber Reserve, Montana.*

BY ROBERT H. CHAPMAN, WASHINGTON, D. C.

(New York Meeting, February, 1899.)

DURING the past two years the writer has been traveling in the Lewis and Clarke timber reserve, locating the boundaries and reference-monuments for the Geological Survey. The Lewis and Clarke reserve lies in northwestern Montana. The region is very mountainous, the main range of the Rocky mountains passing through it, dividing the waters of the Columbia and Missouri rivers.

The mountains do not rise in one important and well-defined backbone, but in a series of parallel ridges, striking nearly northwest and southeast. Between these ridges, and, in general, parallel to them, are the drainage-systems. Beginning at the west, the rivers are the Swan, emptying into the Flathead lake, the South fork and the Middle fork of Flathead river, both emptying into the main Flathead river, which, in turn, empties into the lake of that name.

The continental divide passes through the reserve from the southeast corner to the middle of the northern boundary, and the stream of most importance east of it is the Sun river, which heads well toward the north, and flows southeasterly and then eastward, and, emerging from the mountains, flows across the great plain of the Missouri river.

The southern boundary is drained by the Big Blackfoot river, flowing westward; the northern boundary, by the several branches of the Flathead river. The accompanying map (which is only a sketch, and does not represent the final work of the Geological Survey in this forest-reserve) shows clearly the parallel systems of drainage and ridges.

The westernmost mountain range, the Mission, divides the great valley of the Flathead from the Swan river valley. The

* Published by permission of the Director of the U. S. Geological Survey.

Swan range lies between Swan river and the valley of the South fork of Flathead river.

The next dividing ridge east of the Swan range is the continental divide, which splits near the peak called Silvertip, almost in the center of the reserve.

To the south of Silvertip, the divide separates the South fork of Flathead from the Sun river, Dearborn river, and others of the Missouri system.

Near the Silvertip, the western spur divides the waters of the South and Middle forks of Flathead, and the continental divide, which has kept well to the top of a sharp ridge and has been comparatively straight, drops to a much lower level and becomes very crooked, meandering between the Middle fork streams and those flowing to Sun river.

The next ridge of importance, and east of the divide, is the Sawtooth range, which is the frontal range, and divides the Sun river drainage from the great plain of the Missouri.

In general, the region is made up of a series of limestones, with much calcareous shale, some sandstone, and very little igneous rock.

West of the continental divide, the beds generally dip to the northeast, and east of the divide to the southwest.

These dips are very striking, the perfect bedding of the strata being visible for many miles. For a long distance the divide is the bottom of a syncline, which is broken in a great number of parallel, very continuous faults, which appear as great cliffs—almost perpendicular—making the problem of traveling a serious and dangerous one, even over the known routes, which are few and difficult to find.

The limestones of the Sawtooth range are of light color—buff, yellow and almost white—and, seen from a distance in the sunlight, appear as if snow-covered. Some of the beds contain fossils, marine shells (spirifers?), and crinoid stems, well preserved and in abundance; these beds are Carboniferous.

This range, in itself much faulted, is separated from the main divide by the broad valley of the Sun river, which occupies approximately the strike of a fault. The rocks on the west side of the valley appear in long lines of cliff—of dark red and green shales, which may be Cambrian—capped with the light limestones of the Sawtooth range.

Looking westward from the continental divide, the panorama is one of impressive grandeur and bewildering detail, line after line of cliff, ragged and bare, rising above valleys covered with an unbroken "blanket" of timber.

West of the divide the faulted strata break in cliffs facing southwest. This series of faults is almost entirely in the shales which make up the mass of rock west of the divide, with occasional remnants of the limestone cap.

At the Silvertip the ridge is very sharp; the syncline is bent so sharply as to break, the dips to east and west often approaching one another very closely—to within a few feet.

The valley of the South fork of Flathead shows many minor faults, and probably lies along a faulted syncline. The Swan range, the highest and least broken of the ridges, exposes chiefly the shales, which are continuous for many miles.

The valley of the Swan river is fault-determined and has been eroded by ice. The typical U-shape, with lakes and ponds dotting the floor, is very noticeable.

The Mission range shows the beds of shale again, exposed in the west face by a fault of large throw.

The cross-section, Fig. 1, shows approximately the structure which obtains in general throughout the area. It is constructed along a line drawn through McDonald and Silvertip peaks. The strata have undoubtedly been folded before faulting, but no attempt has been made to show details in the section.

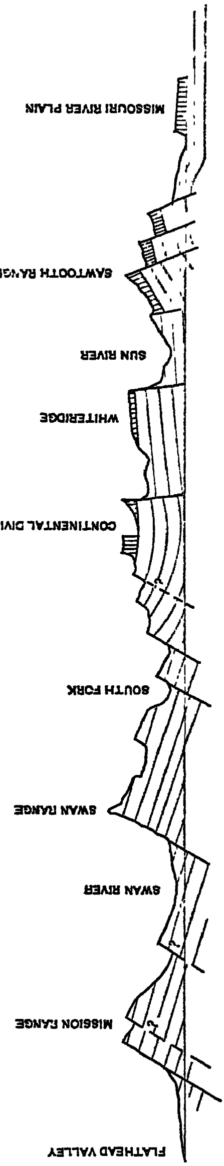


Fig. 1.

APPROXIMATE SECTION ON LINE McDONALD-ROCKY, ALMOST N.E. & C.W.

Scale, 1" = 15 miles

White limestones

Shales and limestones

In the eastern part of the reserve, igneous rocks appear in some quantity in the Lewis and Clarke pass (the southeast corner of the map), and as small dikes in the shales or limestones near the Denton mill, on the South fork of the Sun river. (See map.) On the North fork of Sun river, at the junction of the Middle fork, a considerable quantity of igneous material appears as a ridge, extending for many miles. This ridge is flanked by numerous hot-spring deposits and many living hot springs. Some of these deposits are mined, and the product is put on the market as medicine, which, it is claimed, will cure anything. The business is quite a profitable one.

The most promising indications of gold and copper in the district appear to be more or less closely associated with the igneous rocks. The gold-ores from the eastern part of the reserve are reported by the prospectors as tellurides, but there is no certainty that this is true. Free-gold prospects have been found in the region of the South fork of Flathead river and in the Swan range, where the shales are the same as the gold-bearing series to the north, in British territory.

Igneous rocks probably appear in the heavy ridge—a northeastern spur from the southern end of the Swan range—which runs well out into the valley of the South fork.

In the southeastern portion of the reserve, near Stonewall mountain, there is a copper-property of some importance. Work has been carried on upon it for some years, and while ore has not been produced in shipping quantities, the indications are excellent. The ores are sulphides, and their oxidation-products.

In the northwestern portion of the reserve, numerous deposits of lignite and coal of poor quality are found; but as these have never been systematically prospected, their extent and value are undetermined.*

The lignites usually occur in the valleys, in lake-bed deposits of sandstone and clay, but in some instances are found in very thin beds of small area, in the higher peaks of the continental divide.

* See *Tenth Census*, "Mineral Industry," vol. xv., pp. 704–710.

The Equipment of Camps and Expeditions.

BY PROF. CHARLES H. SNOW, NEW YORK UNIVERSITY, NEW YORK CITY.

(New York Meeting, February. 1899.)

THE engineer has often to penetrate difficult or unknown regions. Mineral, irrigation, boundary and railway problems frequently necessitate journeys through, or long residence in, localities whence sustenance cannot be drawn. The selection and conveyance of provisions, outfit and implements thus become a matter of the first importance. Scientific skill, even of the highest order, is powerless unless supported by the proper appliances and foods. The advance of civilization favors the engineer, in that it is constantly enlarging his facilities and thus reducing his difficulties. Notwithstanding this fact, many are yet brought face to face with the problems considered in this paper.

Distinction must be made between parties which are to be in constant or even occasional touch with a base of supplies, and those which will be for a long time dependent on their original outfit. Again, the requirements of a party on the march are different from those of a fixed camp. The district, season, climate, size and *personnel* of party also influence the character of the outfit. A party that is to be detached from its base of supplies for some time requires a greater variety of food than if it is to be gone for a short time. Much less in proportion need be taken where the journey is not long, so that privation is confined to a limited period. The ability to establish a fixed camp permits a larger outfit than would be possible if the camp were to be moved from day to day. Transportation, climatic and other conditions are thus so varied that lists prepared for one work could hardly be applied to any other without some modification. Lists that have proved successful in some instances may, however, serve as bases to be added to, or otherwise altered, for the case in hand. The mistake usually made is in providing too large an outfit. Every emergency cannot be provided for; so that it is well to take, not what *may* be needed, but what cannot be spared.

The present subject has been exhaustively studied by the military authorities of all great nations. The requirements of the civilian engineer seem to differ, however, from those of the soldier, the sailor, and others exposed to extreme privation. The soldier is disciplined to hardship, and forms a part of a large, well-supported national system, with facilities differing from those controlling private enterprises. The sailor does not have to take into account the question of transportation, which is usually the all-important factor in the work to be specially considered here. Arctic exploration, on the other hand, subjects its small following to such an abnormal maximum of privation, that preparation for physical requirements assumes the position of first importance. The engineer, who is as pronounced in his needs as the soldier or the sailor, may be subjected to privations so severe as to suggest, at least, those of the explorer, and is often responsible for the health of others. Notwithstanding these facts, the writer has failed to find that any attempt has yet been made to collate and compare the experiences of engineers in this important particular.

The organization of any camp or expedition necessitates attention to one or more of the following departments: Transportation; food; shelter; clothing; miscellaneous implements; instruments; *personnel* and medicines. These will be considered in the order given.

TRANSPORTATION.

The difficulties of camp- and field-life increase in direct proportion to the difficulties of transportation. Where a district is open, so that horses can be employed, or where streams or other water-ways permit the use of boats, or when the work can be done in winter, so that provisions can be packed upon sleds, the problem is much simplified. When, however, a camp is to be established, or a party is to travel in some forest- or mountain-district where neither animals, boats nor other means of conveyance can be utilized, and provisions must be packed upon the backs of men, the most careful forethought must be given to its preparation.

The problem of transportation cannot be intelligently treated without some knowledge of the difficulties to be surmounted. While each geographical section is usually distinguished by

local peculiarities (such as those due to climate), topographical difficulties, as a whole, may be conveniently divided, as they are connected with prairies and table-lands, mountains, water-ways, swamps, forests, ice and snow.

Prairies, *table-lands*, ice, or other flat, open surfaces, usually offer, as principal difficulties, those dependent upon temperature and climate alone. The table-lands of northern Mexico, for example, are swept during rainy seasons by storms so severe that gullies, cañons or *arroyos*, such as do not normally obstruct travel, are rendered well-nigh impassable. Similar surfaces in the North are visited during the winter months by high winds and storms, which often interrupt or entirely suspend out-door operations. Supplies can usually be transported over flat, open country by stout, covered wagons; and sleds can be used during the winters in the colder regions.

Mountain districts are characterized either by such abrupt rocky surfaces as exist in the Andes or the Alps, or by gentler inclines covered with forests and traversed by streams, such as may be seen in Arkansas or in the State of Washington. The difficulties of transportation presented by the former class are commonly local, and, although severe, not widespread in their application. The difficulties presented by the more normal type of mountain-lands more frequently encountered by the engineer are often very considerable, because of the forests with which they are covered or of the streams likely to be encountered. Advantage is sometimes taken of the beds of shallow streams by employing them as roads. The climatic differences between the North and the South should also be noted. The immediate concentration of storm-water into streams is often very formidable in the South; while the North is characterized by snow and ice accumulating on the sides of the mountains, to be precipitated later into the valleys below.

Water-ways may extend toward the objective point, so as to facilitate transportation, or they may be unexpectedly encountered as obstructions in overland journeys. A water-way, extending toward the objective point, is an advantage from the standpoint of transportation in direct proportion to the absence of rapids or of shoals. The danger of such travel is much simplified by prior knowledge of the peculiarities of the stream; but in a journey upon a water-course of which no description

is available, constant watchfulness is necessary to avoid rapids, the presence of which is sometimes not evident until it is too late to avoid them. Even with the aid of pilots, failures to pass rapids safely are numerous. Several wrecks occurred daily, during the past season, along the famous White Horse rapids, leading into the Klondike gold-fields, although local pilots were in many instances employed. Shoals are to be feared, as are likewise ponds or bogs, over which a small river sometimes spreads. The latter are sometimes obstructed by grasses or other vegetation to such an extent as to be well-nigh impassable. Rivers, lakes or ponds unexpectedly encountered in overland journeys must be crossed by fording, by felling trees so as to form natural bridges, or on improvised rafts. Solid ice is never to be feared; but solid ice is not apt to form on rapid streams, although the snow by which the ice is covered frequently conceals this fact. A foundation of good ice permits the use of sleds, drawn by horses, dogs or men. The presence of animals, however, is not always wholly desirable under such circumstances, since provision for them, as well as for the party, must be transported.

Swamps may occur in open country or in forests. They are not apt to be large in the former case; in the latter they may be divided according as the water is deep and navigable or as it is shallow. No difficulties are to be anticipated either from the deep-water or open-country swamps. In the Southern States the former are navigable, and the latter, being generally confined to the borders of lakes and ponds, are consequently limited in extent. The shallow-water timbered swamp is, however, very formidable, and can generally be penetrated by pedestrians only. The cedar-swamp of the Lake Superior region, for example, is covered by a growth of white cedar or *arbor vitæ*. The light foliage which characterizes these trees permits them to sustain vigorous branches close to the ground. These meet and cross one another, so that a passage through them greatly resembles a progress through a cultivated hedge. The roots of the trees lie partially out of the mud, and form the most desirable places on which to step. While apparently sound, they are usually slippery and sometimes decayed, so that the traveler, in stepping or springing from one to the other, encumbered by a heavy burden and ob-

structed by the small, wiry branches, is apt to slip or fall. The constant use of arms and limbs required, together with the strain or shock produced by the shifting of the heavy burden upon the shoulders whenever the traveler slips, combine with the abundance of annoying insects to delay and obstruct progress through a territory of such a nature. One of the difficulties to be surmounted in such a district consists in the location of a camp at nightfall. The termination of the normal working-day may find the party where encampment is well-nigh impossible. Under such circumstances it is usually best to go forward so long as there is a prospect of finding a dry or otherwise suitable camping-ground—a discovery which may not be made for many hours. The day's work cannot therefore be confined within the ordinary limits. It is usually best to permit the party to remain for some extra time in camp after such an unusual strain. The so-called tamarack-swamp of the northern Central States differs from the cedar-swamp just described in that there is an absence of the dense under-foliage. The cypress is the characteristic swamp-land tree of the Southern States. The open bog or "muskeg" of the extreme Northwest is thus described by Professor Russell:*

> "The muskeg is a characteristic feature of northern topography. From the International boundary to the Arctic Sea the term is applied to alluvial areas with insufficient drainage, over which moss has accumulated to a considerable depth. These swamps are usually covered with tamarack and fir trees. The typical muskeg is traversed by meandering streams, having deep channels but a scarcely perceptible current. Stagnant pools become coated over with a moss of sufficient strength to temporarily sustain the weight of a man. In places the surface is broken by tall hummocks, the *têtes des femmes* of the *voyageur*, which turn under the foot, and sooner or later precipitate the passing pedestrian into the mud or water below."

Forests are to be considered principally as they aggravate or affect the difficulties due to the presence of mountains, waterways or swamps. They are of themselves difficult in direct proportion to the presence of undergrowth. Surfaces covered by large trees, the lower limbs of which have fallen away, present no obstacles to foot-passengers or pack-animals, while surfaces covered by younger growth are difficult because of

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* *Explorations in the Far North*, by Frank Russell, 1898, page 4. Published by the University of Iowa.

thick under-foliage, and because their plants stand so much closer together. "Windfalls" must be considered. They are the results of tornadoes or of natural decay, and present a spectacle of trees piled upon one another in utter confusion, the trunks and limbs [illegible] and usually penetrated by wiry second-growth saplings. A passage is made over such a district by walking cautiously back and forth, up and down over the trunks and limbs.* It is ordinarily impossible to proceed in a day's march more than two or three miles, as measured in a straight line, over such a district.

A considerable range of experiences may thus be encountered upon surfaces coming under the head of forest-lands. The passage may be over clear ground, between widely separated trunks of large trees; or through the thick, wiry growth of a young forest; or over windfall, or it may be over swamps or mountains, difficult of themselves, but now doubly so through the presence of the foliage. Many contingencies are thus likely to be encountered in forests, and all are frequently encountered within short spaces.

Considerable trouble may be experienced from mosquitoes and similar insects. This is frequently so great as to pass the limit of simple annoyance. Tents hastily erected at nightfall by men fatigued with a long day's march are often invaded by these pests to such an extent as to interfere with rest.

Unless water-ways or other openings traverse a forest in the direction of the objective point, or a party is large enough to construct its own trails or roads, burdens usually have to be borne upon the backs of men whenever a forest is to be traversed.

Snow and ice are to be considered, because, like trees, they distort or change normal topographical conditions. Ordinarily impassable regions may be penetrated, or passable regions rendered impassable, by the presence or absence of ice and snow. Deep, dry snow, such as is encountered in the Northern forests, is very difficult to traverse. Such deposits are sometimes covered by a crust of sufficient strength, improving the conditions of travel. Should the crust be too weak to bear the

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* The origin of windfalls is well treated in Chapter vi. of the Third Annual Report of the Pennsylvania Department of Agriculture.

full weight of the traveler, yet so strong that it cannot be broken or forced aside by the limbs, the passage becomes exceptionally exhausting. The foot must be lifted so as to be placed upon the top of the crust, which gives way suddenly when the full weight of the body is brought upon it. Not infrequently the early morning hours offer a hard crust, which softens later under the influence of the sun, so as to make treading difficult even upon snowshoes; and parties often stop and wait for the night to restore the practicable surface. Deep snow or ordinary crust should never be attempted by heavy draft-animals. When the snow is hard, or the ice solid, a surface is presented, the desirability of which cannot be excelled. Long journeys are sometimes undertaken in the wilder portions of Manitoba and other Hudson Bay provinces in winter, in preference to summer, for these reasons. Heavy vehicles make journeys over the ice bounding the shores of Lake Superior that would not be normally possible through the dense foliage of the adjoining land. Northern swamp-lands, commonly presenting great difficulties, may usually be penetrated with ease during the winter season. Water-ways too shallow to be available for boats during the summer become available for sleds during the winter. Heavy loads can sometimes be transported over a limited extent of deep snow by sprinkling it with water, which, freezing and compacting the snow, often affords a good footing. This method is employed on an extensive scale in some of the lumber-districts of the Northwest.

Supplies are transported either by boats, wagons, sleds, animals, or upon the backs of men.

Boats intended to traverse rapids are sometimes supplied with life-saving appliances, so as to resemble ordinary life-boats. This was the case in the late survey of the cañon of the Colorado by Mr. Robert B. Stanton.* Weight is usually a matter of much importance. A boat that can be lifted from one waterway to another, or be conveyed around rapids or other points of difficulty, is generally desirable. Draft should also be considered. Rafts and scows are often improvised for crossing unexpected bodies of water; and no supply-list is complete unless, in view of such necessities, it is provided with long wire-

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* *Trans. Am. Soc. C. E.*, vol. xxvi., April, 1892.

nails and ropes. A small raft, 6 by 9 feet in size, was once constructed by the writer, of dry cedar logs, fastened with wire-nails and the bark of the "moose-tree." This raft, built in a few hours, carried himself and one companion for five consecutive days down a series of small lakes and rivers. Whenever rapids are to be passed, the provisions should be divided among several boats; or, if there be but one boat, they should be, in part at least, landed and carried around the rapids, to be restored to the boat below.

Wagons may generally be best selected by assuming that they will have to be driven over boulders, stumps, or similarly rough surfaces. They should be provided with tops, wherever storms are liable to be encountered. Tools for making repairs should be placed in every wagon. In each district the selection of vehicles to be thus used as transports is controlled by local customs, which, being founded upon experience, should not be disregarded.

Sleds are sometimes provided with adjustable runners for passing along narrow trails or between boulders. Last season's trail over the White Pass, leading into the Alaskan gold-fields, was of such a nature as to restrict traffic to within a gauge of about 26 inches. Some sleds had to be abandoned, and many delays were occasioned by the necessary alterations of others to meet this condition. Hand-sleds are useful, since they may be drawn by either men or dogs. The Duluth, South Shore and Atlantic Railway [illegible] toboggans during the construction of its road throughout the season of 1887.

Draft- and Pack-Animals.—The best draft-animals are oxen, horses, mules and dogs. Reindeer have lately been suggested for work in the North, but their use is yet in an experimental stage. While mules and donkeys are employed frequently, and oxen sometimes, the main reliance is placed upon horses. The use of dogs appears to be restricted to the drawing of sleds over flat ice- or snow-covered surfaces. Horses and mules should not, as a rule, be employed for long journeys, unless some provision for them can be gathered by the way; otherwise, an undue proportion of the burden must consist in food for their sustenance. Horses trained to the conditions they must encounter are generally to be preferred; Indian ponies, for example, will scrape through a moderate layer of snow, to

find the dried grass below it. Dogs are probably the most economical animals for winter-service in the North, because their food-requirements are so nearly similar to those of man.* The mule and the horse are the best of the lower pack-animals, while man himself must often be relied upon for this service. Horses and mules are provided with pack-saddles over which the burden is uniformly distributed, a task requiring considerable skill and experience. Man is to be preferred as a pack-animal, because his services are available in other ways than in the carrying of burdens. Indian packmen, capable of conveying a burden of 100 pounds throughout the entire day over the roughest country, and who will prepare the meals and camping-ground, are easily procurable. The burden is made up by means of the ordinary pack-straps; the load, being wrapped in the sleeping-blankets, is fastened by the pack-straps, and then adjusted to the shoulders of the carrier.

Food.

Foods suitable for camps and expeditions differ from those available for more ordinary conditions in two respects. First, they are deficient in those imperfectly comprehended vital elements which exist in fresh beef, vegetables or fruit, as compared with cured beef, canned vegetables and dried fruit. Second, they are limited in variety. The first difficulty, while important, is not insurmountable. Life and health have been sustained for long periods on imperishable foods such as are here considered. It is, however, very important that the greatest possible variety should be provided. Foods which are at first acceptable, and which are undoubtedly sufficient in nutritive value, become objectionable if persisted in for too long a period. The digestion and working-efficiency of the consumers are also impaired. Members of the party will work more cheerfully, and resist the influences due to an absence of fresh food for an infinitely longer time, where variety is provided. Variety is obtained by the utilization of the many forms of

* A good pair of dogs can draw 300 pounds over an ordinary frozen surface. A team of five dogs, which can readily haul 600 pounds, costs from $100 to $1000, according to circumstances. It is reported that at Dawson, during the present season, $2500 was refused for a team of five dogs, capable of hauling over 200 pounds each.

cured or preserved foods available, and also by a knowledge of cooking as applied to such foods. A cook experienced in the requirements of camps will provide a considerable variety of dishes from a comparatively small list of elementary food-substances.

Foods suitable for camps and expeditions should be satisfying, easily packed, readily cooked, and as light in weight as possible.

Meats.—The choice of meats is unfortunately limited, so that this subject presents many difficulties. Fresh meats should invariably be preferred to any substitutes, and should be procured wherever possible. The United States Government assumes 20 ounces of fresh meat, such as beef or mutton, as an allowance per man per day. This quantity is presumed to be interchangeable with 12 ounces of cured bacon.* Canned meats must be more or less resorted to, when the period of exposure is to be long. When well prepared, they are probably the best form of preserved meats, save that they are heavier than some of the others. Beef, mutton, turkey, chicken and ham are the principal meats thus prepared. Specifications governing the canning of meats have been framed by the United States Navy Department, and will be found to be of service. The preparation of canned foods should be most carefully superintended; and no product should be selected which has not passed the test of actual experience. Canned meats do not always remain good and fresh in warm climates. This is probably due, at least in part, to carelessness in manufacture. It is asserted that these preserved meats have been concentrated, or otherwise altered, so that less weight is required than if the meat were fresh. Such an assumption can hardly be relied upon practically, save as it may refer to the removal of bone and gristle. It is certain, however, that the per cent. of protein is greater in canned meats. Sixteen to eighteen ounces of canned meat should be specified per man per day.

Meat-pastes or mixtures are frequently employed. Pemmican, an illustration of this class of foods, was originally prepared by the North American Indians, and consisted of dry venison which, after having been pounded or otherwise pul-

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* See U. S. Army *Issue- and Conversion-Table.*

verized, was mixed with fats, the flavor being sometimes improved by the addition of herbs. It is now made from the round of beef, cut into strips, dried, shredded, and then mixed with beef-suet and Zante currants. Pemmican resembles the *biltong* of South Africa. It is sometimes taken on polar expeditions, and can be relied upon to remain good for long periods.*

So-called "Emergency Foods," in which meat, as an active principle, is combined with other food-elements, are manufactured, to some extent, with the purpose of furnishing a more or less complete animal and vegetable food in as small a bulk as possible. The "standard emergency-ration," manufactured by the American Compressed Food Co. of Passaic, N. J., consists of dried meats, meals and vegetables, reduced to convenient form by hydraulic pressure. Three tablets of this compound, with one of compressed and sweetened tea, weigh 1.28 pounds and occupy 27 cubic inches. They are placed in a can of convenient proportions, thus forming what is intended to be an entire day's allowance. The food appears to possess unusual merit as compared with others of its class.† It should, however, be supplemented by other foods. The "concentrated military soup," manufactured by the Tanty Canning Co. of Chicago, was originally prepared by M. Tanty, a celebrated French *chef*, for use in the Russian army. It has since been employed by the government of France. Beef-extract is sometimes combined with partially-cooked bean- or pea-meal, and then placed in films, so as to closely resemble the common sausage. This mixture, known as *Erbswurst*, is prepared in the shape of soup, only a few minutes' cooking being necessary. It is manu-

* The Australian pemmican, as prepared by Dr. Bancroft for the British Army service, consists of beef mixed with 30 or 40 per cent. of fat, flavored with beef-extract. The composition is said to be about as follows: moisture, 2.95; fat, 32 to 42.25; albuminoids, 42.25; other nitrogenous substances, 5.20 to 12; ash, 3.22 per cent. Five ounces of this mixture is said to be equal to 1 pound of beef. (*Report of the Commissary General of Subsistence*, 1894, p. 16.) Pemmican is not generally known in the United States, and is very difficult to obtain. Messrs. Kemp, Day & Co., of New York City, have provided this food for several expeditions known to the writer.

† Since writing the above, tests conducted by the Government at Chickamauga, and reported by the current press, appear to confirm the above. The impression made upon those in charge is said to have been so favorable that the food is under consideration as a government emergency-ration.

factured by the C. H. Knorr Co., of Heilbronn, Germany.* Although this mixture is designed abroad as an equivalent or substitute for meats in emergency-rations, it would be classified in this country among the vegetable foods.

Some of the emergency-foods are undoubtedly satisfying to individuals. It is not so certain, however, that they would meet, as an exclusive diet, the requirements of the majority. They are certainly useful as occasional substitutes, affording an agreeable temporary change. But too great a reliance should not be placed upon them, since preparations of this kind have received their principal tests in Europe, where the requirements for food are not as high as in the United States.

Bacon and ham are almost universally relied upon in the United States, because they are compact, durable, more or less satisfying, easily cooked, and readily procured in any market. Bacon was recommended by the U. S. Commissary General of Subsistence, as the best emergency-meat, after the consideration of separate reports from eight army departments.† Ham differs from bacon in containing much less fat. The two meats may sometimes be combined to advantage. Bacon should be specifically purchased as fat, lean or medium, according to climate or personal preference. The result is likely to be unsatisfactory unless the grade is thus distinctly specified. The recommendation of the U. S. Commissary General, above quoted, was in favor of a preponderance of lean meat. Where bacon alone is to be employed, lean meat should almost invariably be specified, the leanest bacon being sufficiently fat. A larger proportion of fat is permissible where it can be used in combination with ham.‡ Some forms of sausages are useful, because they afford variety. Approximately, thirteen ounces of these meats may be considered as a substitute for twenty ounces of fresh meat, for the conditions now under consideration.

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* The success of the German army during the Franco-Prussian conflict of 1870 has been largely attributed to the use of this substance. As in the case of pemmican, this food is difficult to obtain in the United States except in large quantities. It can be obtained from Messrs. Rode & Co., Sixty-First Street and Third Avenue, New York City.

† *Report* of 1896, page 63.

‡ Ham that is broiled or fried appears to be more concentrated, and therefore more satisfactory than when boiled. Broiled or fried, it may be classified with bacon, while boiled ham may be compared with corned beef.

Desiccated or "crystallized" eggs have been employed as a camp-food to a moderate extent, and appear to be worthy of a more prominent place in the expedition or camp provision-list. These eggs can be prepared in many ways, notably in omelets, to be used in connection with bacon and ham. This substance, as prepared by the La Monte Desiccated Egg Co. of St. Louis, as distinct from some others, was one of the most satisfactory articles in the outfit of a party recently sent, for scientific purposes, into a very remote region, and detached from its base of supplies for more than six months. One pound of the dried product is said to contain the substance of forty-eight fresh eggs. Crystallized eggs should be combined with cold water before heating.

Evaporated eggs are difficult to obtain in the East in small quantities, but may be procured by the case without difficulty. In many Western cities they are employed by bakers, and can be obtained in small amounts. It is reported that the yolks of eggs, which are discarded in the manufacture of prepared albumen for photographic purposes, are wasted. It would appear that a considerable demand might be created for this most valuable substance.

Condensed milk should be employed wherever possible.

Wild game is frequently considered as a resource. A party which is to pass through a section in which wild game is supposed to abound should not, as a rule, depend unduly upon it. The hunting of game requires much time and heavy weapons, such as are otherwise not usually necessary. Moreover, the hunter's success is uncertain and intermittent. The work of the party is more likely to progress rapidly and regularly if the possibility of game for food was disregarded when the outfit was made up. Certainly, reliance should never be placed *wholly* upon game, or any other outside means of support.

Foods Other than Meats.—It is not hard to decide upon foods other than meats. White beans, yellow corn-meal, white flour, Carolina rice, oatmeal, baking-powder, sugar, salt, tea, coffee, chocolate, prunes, raisins, Zante currants, dried apples, peaches and apricots are all available in this connection. All these articles can be prepared so as to remain uninjured for long periods. They meet the requirements for food in this connection, in that they are satisfying, easily packed, readily

cooked, sufficient in variety, and comparatively light in weight. The tomato is an unusually acceptable vegetable, and should be included wherever possible; a product containing as little water as possible being preferred.* The market offers many compressed vegetable foods, some of which are quite useful. Bean- or pea-soup, either in meal, tablets or sausages, is usually very good. One of the best grades of pea-meal is *Erbswurst*, the qualities of which have already been referred to. This substance has been tested by the U. S. Commissary Department, which reports that it is a good substitute for all other dry and fresh vegetables, and that it is most satisfactory when mixed with small pieces of bacon, and used as soup.† The principal objection to *Erbswurst* is the difficulty of obtaining it, save in large cities. Other mixtures of similar nature are no doubt more easily available; and some of them may be quite as good. None of them, however, have been so exhaustively tested. The fact that preparations of this kind are partially cooked is important, as raw beans and peas require long-continued preparation. Soup from *Erbswurst* is not as palatable as that from fresh split peas; yet, during the tests later alluded to, students requested soup from *Erbswurst*, because of its nutritive qualities, instead of that freshly prepared from the best dried peas.

Saccharine has received considerable attention as a substitute for sugar. It is quite certain that it contains no injurious principle, but is, on the contrary, helpful in correcting some of the intestinal troubles due to camp-life. It is clearly distinguished from sugar, in that sugar is a valuable food, whereas saccharine is simply a flavor. Recent experiments are reported to have been conducted in Germany‡ in which sugar was permitted to form a portion of the daily allowance of a considerable number of soldiers; and it is said that the results, when compared with those obtained from men who abstained from sugar, indicated in a very marked degree its value as a food. The writer has particularly noticed the beneficial effects of sugar when greatly fatigued and living upon low diet. At such times it appears to act as a stimulant, probably because,

* Tomato soup-tablets are available where canned tomatoes cannot be used.

† Communication from Maj. C. A. Woodruff, February 12, 1899.

‡ *Sugar as Food*, M. H. Abel, U. S. Dept. of Agriculture.

unlike starch, it is so immediately absorbed. Sugar should certainly never be omitted from camp-supplies, save possibly in case of emergency. Even then its superior qualities are thought to offset any disadvantage due to its greater weight. Two grains of saccharine are said to possess the sweetening-qualities of one ounce of sugar.*

Evaporated vegetables are not good from a nutritive point of view. They give variety, however, and are useful in this respect. Dried onions are one of the most reliable, and dried potatoes one of the least so, of these foods. Dried fruits, as distinct from dried vegetables, should invariably be employed. particularly if the expedition is to be out for some time. Prunes, apricots, peaches, apples and raisins have been found to be satisfactory from every point of view. They are not only valuable foods, but supply one of the best means for the prevention of scurvy. One-fifth of a pound of dried fruit may be assumed as the equivalent of one pound of fresh or canned fruit. Numerous varieties of canned vegetables are available where weight is not a consideration. Many, if not most, of the compressed foods specially prepared for the requirements of camps have but little practical value. The stomach requires physical exercise as well as nourishment. This exercise cannot be obtained unless the food is to some extent bulky. A desiccated or compressed food should be of such a nature that bulk can be given to it by the addition of water. An adjustment must always be made between necessary and needless waste.

Citric acid is desirable as a substitute for the natural acids of fruit. When in solution, the flavor resembles that of lemonade. Concentrated or "evaporated" vinegar is more or less pure acetic acid, colored with caramel and flavored with extractive. Chemically pure acid (of 80 per cent. strength) may be handled with perfect safety, and, when diluted with 15 times its own bulk of water, will afford excellent vinegar, par-

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* It is well known that large quantities of sugar are demanded by the lumbermen of the northern woods, who employ it with great freedom upon beans, pork and other food. The negroes employed upon sugar-plantations are said to use considerable sugar. The writer has passed through several consecutive days of unusual toil without much difficulty, depending principally upon crude sugar, other provisions having failed.

ticularly if flavored with estragon or some similar substance. White beans are universally relied upon in camp-diet. Their high percentage of protein renders them one of the best vegetable substitutes for meat. One ounce avoirdupois of white beans, measuring 1¼ fluid ounces, increased after cooking to 2¼ ounces in weight and 3 fluid ounces in bulk.

Hardtack must be distinguished from pilot biscuit, which is ordinarily sold as hardtack. The former is harder, and, while less palatable, is more durable.

Rice is one of the valuable articles in this connection. Good, clean, large-kerneled Carolina rice should be selected. One ounce avoirdupois, [illegible] 1½ fluid ounces, increased after cooking to 5 fluid ounces in bulk and 6¼ ounces in weight.

Tea is generally used by the inhabitants of cold climates, while coffee is preferred by the inhabitants of warmer ones. Tea and coffee have little if any importance as nutrients, but are valuable in that they prevent waste and are harmless stimulants. It is important that personal preference be gratified as regards tea and coffee. An inhabitant of a temperate climate will usually retain his preference as regards tea or coffee when transported to some other climate. Tea is, generally speaking, to be preferred to coffee, in that it is much lighter, one-half ounce of tea being an equivalent of two and a half ounces of roast coffee or three ounces of green coffee. Roasted coffee is to be preferred in traveling, while green coffee may be provided for camp-use.

Chocolate is a food, the value of which is not, as a rule, comprehended in America. In France and in some other European countries, stick-chocolate is devoured as a regular article of diet. In the United States it is regarded as a confection rather than as a food, and the objection urged against it is that it is indigestible. Chocolate is almost invariably easily digested in considerable quantities by those who exercise freely. It is at least as digestible as bacon. It is the experience of the writer, who has invariably employed it for some years, that members of the party who at first regard it with little seriousness, soon begin to depend more or less upon it.*

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* The "German" Sweet Chocolate, manufactured at Dorchester, Mass., by the Walter Baker Company, is very satisfactory.

Raisins are valuable as a convenient form of dried fruit edible without cooking. They are also serviceable when boiled with rice, prunes, or other fruit. Raisins are much employed in many of the lumber-camps of the Northwest. They should be kept in tight packages.

Canned vegetables should be selected with the greatest care. None should be chosen that have not previously been tested as regards palatability, as well as general condition. Experiments in this connection are not permissible. The same point does not apply to canned fruits with the same emphasis, since canned fruits are not relied upon to any great extent for nourishment, and also because canned fruits are more apt to be good than some kinds of canned vegetables.

Selection and Quantity.—The great bulk of almost all the fresh foods in common use is made up of water. Some foods permit the evaporation of superfluous water without deterioration of the food-substances themselves. The majority of these resume most, if not all, of their original bulk when brought again into contact with water, as they must be during the processes of cooking. Such foods are of great value for the purpose under consideration. An effort should be made to secure as many of them as possible; the resulting list being then supplemented by such other articles as have been proved to be satisfactory for other reasons.

Military authorities recognize the necessity of grouping foods together, so as to meet the requirements of different contingencies. The "Reserve," "Travel," "Emergency" and other rations have been thus called into being. The same necessity for recognizing different requirements exists in civil life. Food-combinations that seem to be best fitted to meet the contingencies of difficult and of easy transportation, of fixed and moving camps, and of emergencies, have therefore been suggested. It is not expected that any one of these combinations can be exclusively adopted, since the work of the civilian, to a degree as great, if not greater, than that of the soldier, exposes him to unexpected contingencies, so that all of the requirements noted are possible within a comparatively short experience. The distinctions between such classes of food must be comprehended, however, if the outfit is to be made up intelligently; and in many cases they must be carried into effect throughout.

Where exposure is to be endured for a short time only, it will usually suffice to rely upon a few appropriate articles, such as can be easily cooked, or, perhaps, need not be cooked at all. Health is not preserved, however, if these abnormal conditions are permitted to exist beyond a very few days. Allowances for such conditions would be entitled "emergency-rations." The saving in weight effected by cutting down a full day's ration to the smallest quantity upon which life or some degree of health can be preserved, is but small. The principal differences, therefore, between rations that are to be used in emergencies or upon the march, and those that are to be used in camp, should be as much as possible along the line of absence or presence of water, variety and ease of cooking. Weight would seem to be less important in emergency-rations than in other cases. The emergency-ration is intended at most for only a very few days. Several ounces daily more or less would therefore result in a total so small that it need hardly be considered. Adding several ounces daily, however, to rations that are to be continued for weeks or months would be more serious. It would seem, therefore, that an emergency-ration should be liberal in quantity, without much regard to weight, but characterized by the simplicity, ease and rapidity with which it can be cooked.

Parties established in well-adjusted fixed camps, where provisions have been unpacked and cooking-facilities have been developed, require, and can employ, a larger variety of foods than those stopping at short intervals, in quickly improvised camps, along the line of a journey. The difference between foods selected where transportation will be easy, and those selected, either for fixed camps or for moving men where transportation is not easy, should lie, as much as possible, along the line of weight of uncooked food. Parties traveling easily by boat, for example, can employ canned fruits; whereas dried fruits, which weigh approximately one-fifth as much, would have to be utilized by those looking forward to transportation over some difficult trail.

Climatic and personal considerations always influence the selection of foods. The Esquimau, for example, requires foods abounding in fats, while the inhabitants of tropical countries require lighter foods. Tea appears, in a general way, to be more appropriate to the North, and coffee to the South. Fruits, peppers

and highly seasoned foods are also characteristic features of the Southern or tropical diet. The food-requirements upon a cold day are much in excess of those upon a warm one. Other distinctions also exist. Foods upon which certain nations rely are not always suited to the requirements of other nations. The German diet, for instance, does not appear satisfactory to the Frenchman; while a diet satisfactory to a French soldier would be insufficient for the requirements of an American civilian. A certain amount of adaptation may be expected, where people of one region are transported to another.

The subject of quantity is a difficult one, owing to the variation due to weather, climate, labor and personal habits. It is frequently customary to order supplies for parties in bulk, without much attempt at mathematical apportionment, trusting to chance to provide new supplies when the original ones are exhausted. Supplies can be purchased in such large quantities as to be clearly beyond the limit of requirement. Government data are here of imperfect service. The civilian usually requires different foods from those satisfactory to privates in the regular army. American studies in this direction are invariably to be preferred, for American conditions, to those made in Germany or elsewhere, even although more attention has been given to this subject in Europe than in America. Conclusions based upon experience are invariably to be preferred to those derived from chemical analyses. Combinations of food could be arranged that would be theoretically sufficient for life and health, while practically insufficient to preserve either. The chemistry of the vital elements of food is not yet perfectly comprehended. In the absence of other data, foods may be theoretically measured or compared by the presence of a series of substances called protein, and by other series of substances classified as fats and carbohydrates.*

The former are supposed to be valuable in promoting or

* The chemistry of foods is yet indefinite. Protein, including the albuminoids and gelatinoids, is divided into series called proteids, nitrogenous extractives and amids. All are particularly associated with such foods as beef, eggs, wheat and nutritious vegetables. Fats are present in most meats and vegetables, while carbohydrates are in gums, sugars and starches. The protein series is presumed to make and to protect tissue, while fats and carbohydrates produce heat and energy. The disintegration of tissue may result in heat and energy. A lean man, fed upon lean food, may therefore be as warm and energetic as one who requires and can

sustaining tissue, while the latter are associated with warmth and muscular action. Prof. W. O. Atwater, one of the foremost American authorities on this subject, has established a tentative standard of 150 grammes of protein and 4200 *calories* of energy as the requirement of a man at hard muscular labor. The average of fourteen dietary studies of mechanics' families in this country indicates a daily food-consumption corresponding to 103 grammes of protein and 3465 *calories* of energy. The value of all foods must obviously be judged by other standards than those established by chemistry, even if these were entirely reliable. Digestibility and palatability are always important; while foods that are intended for special purposes, such as those called for by camps and expeditions, must, as has been indicated, be judged according to weight, appropriateness, climate and other standards.* After substances have been selected so as to accord with all of these more important standards, they may then, perhaps, be measured or compared in terms of their protein and of their energy. It is believed that, although the following lists have been compiled with a view to meeting average conditions, they may also be employed as bases for others, intended to meet extraordinary conditions.

Table I. contains series of provisions suitable for camps and expeditions under average American conditions. The different foods are grouped together, so that a day's allowance may be formed by selecting any one substance, or a lesser quantity of two or three substances, from each of the several groups of meats, breads, vegetables, etc. The protein and energy-values of each one of the substances thus enumerated are given for

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assimilate fats and carbohydrates, which are theoretically more distinctly heat- and energy-producers. Protein is measured in grammes, while heat and energy, being interchangeable, are measured in terms of heat, the *calorie* or unit being the quantity of heat required to raise the temperature of one pound of water 4° Fahrenheit. The protein-value of food is determined by the ordinary quantitative means, while the heat- or energy-value is determined by the burning of fats, starches or similar foods in an apparatus called a calorimeter. Studies along this line are being conducted at Middletown, Conn., by Prof. W. O. Atwater.

* The weight of the regular U. S. field-ration is 3.21 pounds.

The weight of the regular travel-ration is 2.43 pounds.

The weight of the regular emergency-ration, authorized 1896, is 2.07 pounds.

The bulk of the authorized emergency-ration is 125 cubic inches.

TABLE I.—*Meats, Breads, Vegetables and Other Foods Particularly Suitable for Camps and Expeditions, with Protein and Energy-Value of Each.*

	Substance.	Protein. Grammes per Ounce.	Energy. Calories per Ounce.
Meats	Bacon,	2 64	175.6
	Ham,	3.85	104 0
	Evaporated eggs,	12.58	138.7
	Bacon and ham,		
	Bacon, ham and evaporated eggs,		
	Canned corned beef,	7.45	80.6
	Canned fresh beef,	7.22	89.1
	Canned fresh fowl,		
	(Fresh beef),	(4.19)	(65.0)
Breads.	Hardtack,	3.52	112.2
	White flour,	3.11	100 9
	White bread,	2.66	75.9
Vegetables.	Oatmeal,	4.76	115.6
	Corn-meal,	2.63	104.4
	Farina,	3.12	104.1
	Cracked wheat,	3 60	106.2
	Hominy,	2.41	103.4
	Rice,	2.21	102.2
	White beans, dried,	6.38	100.0
	Lima beans, dried,	5.13	101.2
	Pease, dried,	6.97	103.4
	Lentils, dried,	7 28	101.2
	Pea-meal (*Erbswurst*).	6.97	103.4
	Canned tomatoes, concentrated,	1.70	32.8
Beverages.	Tea,		
	Coffee (roast),		
	Chocolate,	3.65	178.7
	Cocoa,	6.12	145.0
Sugar.	Sugar,		116.2
	Saccharine,		
Condiments.	Salt,		
	Pepper,		
	Baking-powder,		
	Vinegar, concentrated,		
Milk.	Condensed milk,	2.52	94.7
Fruits.	Raisins,	0.65	90.3
	Prunes,	0.51	74.4
	Dried apricots,	1.33	80.6
	Dried peaches,	1.33	80.6
	Dried apples,	0.45	84.4
	Canned peaches,	0.19	13.7
	Canned pears,	0.08	22.2

A day's ration to be made up of one item from each of the several groups, or a lesser quantity from two or more varieties in a group.

An exception is made in the case of vegetables, where one item should be selected from each of the several divisions under one head, or three vegetables in all, tomatoes also being included wherever transportation permits.

ounces. The writer is indebted to Professor Atwater for the latest figures in this connection.

Table II.—This table groups foods best fitted to meet the several conditions of difficult and easy transportation and emergencies. The quantity that is to be taken of each substance is noted, with the corresponding totals of protein and energy. The selection of appropriate foods and figures as to quantity are based upon actual experience, checked by comparison of available data. The lists, with slight variation, have been employed in several instances, and have been found to be satisfactory as to variety. A series of experiments, conducted upon a small body of carefully selected students* in order to ascertain what would be a liberal proportion of the foods in question when thus used in combination, indicates that the amounts allowed are at least approximately correct for average conditions.

Waste.—Cans, bones and other waste must be taken into account.

Two-pound tins of canned corned beef were found to consist of 25½ ounces meat and 6½ ounces can. Twenty-ounce cans of condensed milk of 17½ ounces milk and 2½ ounces tin. Cans of average good tomatoes weighing 2 pounds 9 ounces were composed of 2 pounds 3 ounces tomatoes and 6 ounces tin. These same tomatoes, when evaporated to ordinary table consistency, weighed 1 pound 10 ounces, or, approximately, 65 per cent. of the original package. The larger the can the less is its proportionate weight. Canned corn, succotash, or vegetables other than tomatoes, contain much less water than tomatoes, and may be calculated without further deduction than the weight of the can. This same care in determining the waste of other useless parts does not apply in the same degree to canned fruits, since canned fruits are not relied upon for nourishment. Meats differ in their proportion of waste. Five pounds of superfluous fat, bone and rind, have been removed from a twelve-pound ham. At least 5 per cent. of bacon consists of rind. Ham may be relieved of much of the superfluous fat and all of the bone and repacked without injury.

* Tests of this kind are not entirely reliable, since change of diet is always likely to be immediately beneficial. The fact that each student showed a tendency to exceed the full allowance of seven ounces of sugar daily is thought to be of interest.

It is usually wise to recognize the fact that some claims will be made upon the party in the way of hospitality or the actual relief of others. It would hardly be practicable to calculate so closely that such contingencies would embarrass the outfit. It is well to remember that such claims will have to be met. Deterioration, loss and detention by accidents must also, at least, be considered.

Packing.

It is often convenient to divide everything, save fresh meat, proportionately, so as to form packages of perhaps fifty pounds each. Each package may be placed in an air-tight can, with lids and seams tightly soldered. These cans should not be round, but flattened upon the two opposite sides, so that they can be readily packed and carried. Matches should be included in each can, and one can only should be opened at a time. Where articles are thus divided among several packages, the contents of each one should be checked twice before it is finally enveloped. Paper should not be used for making up packages, because of its disposition to soften under moisture. Canvas bags should be employed. Where provisions are to be transported upon the backs of men, the packs are made up by placing cans or canvas bags filled with provisions in the center of the sleeping-blanket, which is then folded around the load and fastened with the ordinary pack-strap. The load is then adjusted to the shoulders. Attention has been called to the wisdom of dividing the outfit among several boats, when passing rapids, or among several parties when upon the march. Every article should be selected, if possible, by the leader personally; and each parcel should be packed in his presence, or in the presence of some competent representative.

Shelter.

Shelter may be classed as the camp is to be permanent, or as it is to be moved from day to day. A large tent, such as would be useful for a permanent camp, is sometimes too heavy and difficult of erection to be employed upon the march. Permanent shelter is obtained by the use of tents or by the construction of log- or bark-houses. A light wooden frame, covered with tar-paper, is sometimes employed. Portable wooden or metallic

houses may be relied upon if transportation is not an objection. Light shelter- or dog-tents, like those employed for military purposes, are very serviceable upon the march. A party must necessarily often adjust the requirements of the march with those of the fixed camp, so as to avoid duplication.

CLOTHING.

Cotton cloth should not be employed, because it is a poor protector against heat or cold. It is also inflammable, and, when wet, is difficult to dry. A tough cloth that will not readily tear should be preferred. Attention can profitably be given to the subject of foot-gear. Sore feet are a constant menace to the welfare of an expedition. A single man thus affected may impede or obstruct the entire work. A shoe should not be depended upon, unless it has been broken in or otherwise tested. Leather or top-boots should not be chosen by those who are not accustomed to wearing them, as they are apt, when new, to create sores upon the ankles. The rubber boot can only be employed for limited periods and in fairly cool weather, and can never be worn with comfort for any extended time. This is particularly the case if the weather be hot. The unlined gum boot is to be preferred to the glazed lined boot, because of its wearing qualities, and because the interior of the lined boot can be more easily dried when occasion requires. The shoe-pack, which is a kind of soled moccasin, is very serviceable, and is procurable from most of the supply-stores in the West. These shoe-packs are ready for immediate use, and are particularly good when conditions such as those existing in forest-lands are to be encountered. The felt boot, or German sock, is serviceable in cold climates, where there is much dry snow. It is buckled above the knee and worn with a light over-shoe. When a variety of temperature- or moisture-conditions are to be encountered, or when some unknown district is to be penetrated, an ordinary stout English walking-shoe may be selected with but little risk.

Each member of the party should be provided with one or more pairs of woolen blankets. Sleeping-bags are to be preferred whenever the work is to be carried into a cold climate. They are composed of thicknesses of warm water-proof material, and can be drawn about the body so as to furnish almost complete shelter.

Miscellaneous Implements.

Camp-stoves or Dutch ovens are conveniences which should not be omitted where weight is not an object. The weight of a stove is comparatively small, while, by its use, the labor of preparing fuel is reduced to a minimum, and good fires can be made in rainy weather. Dutch ovens make cooking possible that could not be accomplished with ordinary open fires.* Camp-kettles, frying-pans and coffee-pots are the only other necessary cooking utensils. Kettles are manufactured so as to be placed one within another, several thus occupying the room of one. Copper kettles are generally preferred. They should invariably be rivet-fastened, no solder being permissible. Aluminum is available in this connection, and should be employed as much as possible. One or more axes are indispensable; and other tools should be added if the camp is to be permanent. Matches, rubber or black varnished cloth, cheese-cloth and mosquito-netting, strong twine, needles, thread, long wire-nails, soap, lead-pencils and paper should be included. Matches which do not soften or suffer injury from dampness should be preferred. Black varnished cloth is light and cheaper than rubber-cloth, and will do as well for short periods. It is employed to protect the cameras or similar delicate instruments during the day-time, and may be spread upon the ground for sleeping at night. Cheese-cloth is light, strong and useful against the smallest insects. It is frequently more satisfactory than mosquito-netting, while, as distinct from the latter, it can be employed for many other purposes, such as bandages when accidents occur. Long wire-nails are serviceable for building rafts for crossing unexpected lakes and rivers. A few of these nails will save long hours of exertion, otherwise made necessary in creating a serviceable float.

Attention has been called to the doubtful wisdom of including heavy weapons for the hunting of game; but fishing-tackle, weighing but little, may be of service.

Instruments.

The selection of instruments will obviously depend upon the work for which the camp or expedition is to be conducted, and

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* "Alcolia," or the so-called solidified alcohol, is very serviceable in replacing the more bulky liquid alcohol, required for alcohol-lamps or stoves.

must largely be influenced by the wisdom or preference of the officer in charge. The chance of error in this direction is usually less than in any other. Instruments are generally selected with the greatest accuracy. The work is sometimes embarrassed, however, because equal attention is not expended upon the more common-place subjects of food and clothing. Besides such special instruments as are indicated by the nature of the work, some others should almost invariably be considered. Every member of the party, for example, should be provided with a small pocket-compass. A large compass, the needle of which should not be sensitive, so that it will come quickly to rest as soon as the instrument has been placed in position, is most useful in guiding the party through swamps or similar sections, where a sort of rude navigation must be practiced in order to keep account of its position. It is best to ascertain beyond question that every member of the party has become familiar with the practical workings of this instrument. An aneroid barometer is generally advisable.* Surveying, astronomical or similar instruments should obviously be as light and compact as possible. Combination-instruments should at least be considered. Telescopic tripods are convenient in forest or mountain sections. A camera should always be included if possible. Although films are unsatisfactory, they may occasionally be used at the beginning of the work, being forwarded to some photographer for development until outside communication has been suspended.

PERSONNEL.

Every effort should be made toward concentration. Each member of the party should be able to perform several duties. Labor cannot be divided or exactly allotted in this, as in other work. Good nature, physical strength and common sense are important. It is always fortunate when the several members of a party are congenial to one another, since they must necessarily depend so much upon one another for companionship. It is usually better to fill the lower positions with men drawn from localities as near the work as possible. There is a saving in transportation, and a probability of greater usefulness and local knowledge, than when men are selected at some headquarters, because of influence or their general reputation.

* Hicks, of London, manufactures a barometer that has been found very satisfactory.

Local men are usually more pliable than those appointed through influence at head-quarters. They can be discharged more easily, and are commonly more modest in their demands.

Medicines.

A large party is sometimes provided with a surgeon. This is particularly the case if it is to be gone for some time. It usually happens, however, that injury and sickness are not taken into account; so that when these emergencies arise they must be met, if at all, by the head of the party. Fortunately, men subjected to out-door conditions of life are usually quite healthy. Sickness will arise, however; or, more often, accidents will happen. At these times the head of the party is usually looked to for assistance. Where a medicine-chest must be entrusted to one who is not a physician, it should contain only such safe and well-known remedies as are clearly indicated by indispositions of the more ordinary types.

It is difficult to know just how much medicine to provide. It is not sufficient to take a small sample of each remedy selected. If any one medicine is required, a considerable amount of it is likely to be necessary. Although it is probable that only one or two things will be needed, a sufficiency of each one of the many things that go to make up the chest should be determined upon. A medicine-chest can be put up more economically for three persons than for one, since it is not likely that each one of the three would have the same needs. Three persons should not require more than twice as much as one person.

Dry medicines should be preferred to wet medicines, because of danger from freezing, as well as because there is a saving in weight. Wherever fluid extracts are selected, they should be placed in bottles of the ordinary kind, closed by cork stoppers, unless the fluid is of such a nature as to attack the cork. Each article should be carefully purchased from some reputable firm in that line, and not from a general equipment-house.

The following remedies may be advantageously considered in this connection: quinine, compound cathartic pills, bismuth, sub-nitrate, "Sun" cholera-mixture, cough-mixture, borax, paregoric, tincture of iron, acetanelid, chlorate of potash, citric acid, vaseline, mustard-plasters, belladonna-plasters, toothache-

plasters, carbolic salve, chloroform-liniment, iodoform, "blue ointment," absorbent cotton, aromatic spirits of ammonia, and whiskey. These medicines are sufficient for the treatment of such probable and ordinary indispositions as malaria, fevers, constipation, diarrhœa, dysentery, inflamed eyes, sore throat, toothache, sprains, bruises, wounds or shock. It is suggested that the head of the party should become familiar with the action of these simple remedies, and that he should also understand the principles of camp-hygiene. He would do well to receive such instruction as is given under the name of "first aid to the injured." The distinctions between the conditions of travel and those of fixed residence apply here as elsewhere. The indispositions likely to occur upon the trail are augmented by a new series, as soon as the party is established in a fixed camp. The literature on camp-hygiene is voluminous and exhaustive. The causes of such fevers as are associated with camp-life are well understood, so that little excuse for their prevalence appears to exist. Water should be boiled for some minutes before use, and camp-drainage should be attended to. Much depends upon the location of a camp. Trouble will usually be experienced in enforcing rules with relation to the boiling of water, and other customs upon which the health of the camp so greatly depends. Men who will not hesitate to obey any directions in the line of ordinary duty, will hesitate when requested to dig trenches or arrange drains, the need for which they do not comprehend. The selection and conduct of the camp are quite as important as the food and general equipment. Men upon restricted or unusual diet should not be subjected to unhealthy conditions. The literature on first aid to the injured might well be increased by such a treatise as would include not only such subjects as wounds, shocks or accidents, but the more common forms of sickness. Such a treatise might be framed for use by the trained scientist, as distinct from the average layman.*

TABLE III.—*Medicine Allowance Per Man Per Year.*

Quinine, 100 to 400 2-grain pills, according to district.	Vaseline, 5 ounces.
	Mustard-plasters, 10.

* It is understood that such a treatise is in preparation by Dr. W. H. Greanelle, of New York City, from whom the writer has received assistance in the present connection.

Compound cathartic pills, 30 to 50.
Bismuth sub-nitrate, 150 5-grain tablets.
"Sun" cholera-mixture, 75 tablets.
Cough-mixture ("Brown's mixture"), 100 tablets.
Borax, 3 ounces.
Paregoric, ½ ounce.
Tincture of iron, ½ ounce.
Acetanelid, 60 to 100 2-grain pills.
Chlorate of potash, 30 5-grain tablets.
Citric acid, 1 pound.
Belladonna-plasters, 20.
Carbolic-salve, 5 ounces.
Chloroform-liniment, 3 ounces.
Toothache-plasters, 20.
Iodoform, 1 ounce.
Blue ointment, 5 ounces.
Assorted bandages, 1 pound.
Absorbent cotton, 1 pound.
Aromatic spirits of ammonia (rubber-corked), 2 ounces.
Whiskey, 1 quart.

Quinine.—Antidote and preventive for malarial diseases. Also tonic. Malaria recognized by headache, fever or chills, recurring after more or less regular intervals. Dose for developed case, 20 grains, taken several hours before expected attack. Repeat for one or more days. Afterwards lesser doses, distributed throughout day. As preventative when in malarial country, 8 to 10 grains daily. As tonic, 6 grains in three doses before eating, continued for one or two weeks. Extreme doses of 40 grains tolerated by most adults without danger or great discomfort. Others suffer with 30 or even 20 grains. Large doses should be given in several parts, with intervals between, and not continued beyond a day. Select 2-grain gelatin-coated pills; pack in tight bottles of 100 each.

Compound Cathartic Pills.—For constipation; do not omit. Preparation is standard; employ as required.

Bismuth Sub-Nitrate.—For diarrhœa. Compressed into 5-grain tablets; use one every two or three hours until relieved.

"Sun" Cholera Mixture.—For violent diarrhœa with pain, dysentery and cholera. Now procurable in tablets, each representing one teaspoon of mixture. Dose, one tablet hourly for several hours, then one every three hours until relieved. Remain quiet, restrict diet, removing cause if possible. Dysentery may require additional treatment, as paregoric (see Paregoric), bismuth and stimulant (as brandy). Danger is from exhaustion or hæmorrhage. "Sun" mixture also good after exposure to cold or wet, as it promotes warmth.

Borax.—Inflamed eyes. Dissolve as much as possible in small quantity of water. Drop in eyes. Harmless.

Paregoric.—Label "Poison." Exercise care. Paregoric a dilute solution of opium. Use after "Sun" cholera mixture for dysentery. Dose, 10 drops in water, repeated every two hours until relief from diarrhœa. In severe cases 15-, 20- or even 30-drop doses, until drowsiness. Resume after reappearance of diarrhœa. Exercise judgment in use of paregoric, because of easily formed opium habit.

Tincture of Iron.—Useful tonic when upon low diet. Need indicated by continued whiteness of lips. Three 10-drop doses daily, largely diluted with water. Take upon full stomach.

Acetanelid.—Use for neuralgia or headache. A coal-tar compound, similar to, often substituted for, but safer than, phenacetine. Obtain 2-grain tablets. Dose, two grains, repeating after half hour, if necessary. Six doses daily for several days in extreme cases. For neuralgia of face and headache, suspected to be due to malarial conditions; add small doses of quinine. Extreme daily allowance of acetanelid, 12 to 15 grains.

Chlorate of Potash.—Sore throat. Dissolve 5-grain tablet in one-third glass of water and gargle. Poisonous if swallowed in quantity. Bandage throat in warm compress

Citric Acid.—Scurvy preventive. Regard as food, use as desired, sweetened, diluted with water.

Vaseline.—Use as required.

Mustard-Plasters.—For cold on chest, pains in chest or stomach. Use as required. Moisten before using.

Belladonna-Plasters.—Pains of muscular rheumatism, neuralgia, lumbago, etc. Bathe the part, dry well, and apply plaster of proper size, renewing if necessary after a day or two. Chloroform liniment preferable.

Carbolic Salve.—External dressing, sores, burns, cuts or other wounds. Composed of 1 per cent. carbolic acid in vaseline. Apply when necessary.

Toothache-Plasters.—Apply when needed.

Choloroform-Liniment.—For external application. Muscular pains, rheumatism and neuralgia. Similar in result to belladonna-plasters. Apply small quantities gently but thoroughly, afterwards warmly covering part. Composed of one part choloform, two parts of either mineral oil or soap liniment. Mix well. Dangerous to eyes.

Iodoform.—Label "Poison." For external application only, or sores, cuts or other wounds, especially if redness, tenderness, suppuration or signs of inflammation exist. Use only in small quantities and over small areas. Use carbolic salve over areas larger than a few square inches. Excessive external use of iodoform r sults in delirium. Mix pinch of iodoform with scant teaspoonful of vaseline and apply in form of salve.

Blue Ointment.—Destroys certain forms of vermin, as lice, etc. Shave, cleanse with soap, then apply small quantity of ointment, rubbing in with hand; protect by soft cloths.

Assorted Bandages.—Prefer 1-inch and $1\frac{1}{2}$-inch widths.

Absorbent Cotton.—To dress and protect wounds.

Aromatic Spirits of Ammonia.—Heart-stimulant in case of fainting, over-fatigue or prostration, or as substitute for whiskey in cases of drunkenness. Dose, half teaspoonful in little water. Repeat in half hour if needed. One teaspoonful may be used in extreme cases. If unable to swallow, apply by inhalation similarly to salts, camphor, cologne, etc.

Whiskey.—Shock, prostration, bites of serpents.

The writer has consulted, among other authorities, the various publications of the experimental stations connected with the United States Department of Agriculture, as well as those published by the Commissary Department of the United States Army. He is under obligations to the engineers of several of our Western railways, to Mr. William Northrop, of St. Louis, Mo., and to Professor Robert W. Hall, of New York University, as well as to the students who have assisted him in his experiments.

Improvements of the Spring Valley Coal-Mines.

BY J. A. EDE, SPRING VALLEY, ILL.

(New York Meeting, February, 1890.)

THE property of the Spring Valley Coal Company, situated in Bureau county, Ill., comprises something more than 30,000 acres of coal-lands, on which have been opened four mines, designated as Nos. 1, 2, 3 and 4. Figs. 1, 2, 3 and 4 are plans of the first three; and Fig. 7 is a view of the surface-plant at No. 4, the workings of which it is not necessary to illustrate, as this mine has been practically merged in No. 2. No. 4 shaft is only 500 feet from No. 2, and both are ventilated by the same fan, and are in the same circle of air-supply. In speaking of No. 2, we now include No. 4.

The system pursued in all the mines is "long-wall advancing," and the shafts are all vertical.

The seam worked is locally and commercially known, in the Illinois series, as No. 3; but its position in the geological series is that of No. 2. It averages in thickness about 42 inches, and has no partings, but mines in rectangular lumps, which stand a large amount of handling before breaking. An analysis made from Colliery No. 1 gave the following:

	Per cent.
Moisture,	1.45
Volatile combustible matter,	47.27
Fixed carbon,	41.97
Sulphur,	2.46
Ash,	6.85

Plate 6 shows a photographic view of this seam. The staff seen in the view is 37 inches long.

The table on page 188, recorded in my office, which I presume to be correct, may be of interest.

The bottom is fire-clay, varying in thickness from 6 to 24 inches. It affords what is considered good mining-ground.

The roof immediately above the coal is a dark shale, lying in small bands, from 4 to 9 inches in thickness. Between the

Results of Tests Made by Quartermaster's Dept., U. S. A.

Basis, One Cord of Standard Cord-Wood.

Name.	State.	Character	Pounds of Equivalent	
			To One Cord of Standard Oak Wood	To One Pound of Spring Valley.
Spring Valley..........	Illinois.	Bituminous Nut.	2251	1000
Pinon	Colorado.	" "	2794	1015
Branch Mine	Illinois.	" "	2853	1036
Hocking Valley........	Ohio.	" "	2971	1079
Girard	Illinois.	" "	2840	1032
Lyfords	Indiana.	" "	3015	1096
Streator....................	Illinois.	" "	3076	1118
Boulder Valley	Colorado.	" "	3176	1156
Marshall	Colorado.	" "	3373	1226
Burlingame...............	Kansas.	" "	3301	1190
Scranton	Kansas.	" "	3918	1292
Starr	Colorado.	" "	3929	1246
Osage City...............	Kansas.	" "	3710	1350

layers there is a ferruginous substance which, after being exposed to a gob-fire, looks like jasper, and gives the ground a very marked appearance.

Twenty feet above the No. 3 vein there is a small seam of carbonaceous substance called the "black shale." When there is a fall of any extent in the mine it generally extends up this shale; and when the management was endeavoring to confine the fire raging at the old No. 1 shaft, every effort was made to have all the brick-stoppings extend above this shale.

The result of drilling in different parts of the property gave the following section:

	Thickness. Ft.	In.	*Depth to Bottom.* Ft.	In.
Surface, ...	10	0	10	
Dark soapstone, ...	6	0	16	
Limestone, ...	4	0	20	
Soapstone, ...	30	0	52	
Sandy shale, ...	38	0	90	
Soft sandstone, ...	6	0	96	
Dark sandstone, ...	12	3	108	3
Coal, 1st vein, ...	3	0	111	3
Horseback, ...	1	0	112	3
Fire-clay, ...	4	0	116	3
Soapstone, ...	5	0	121	3
Dark slate, ...	17	0	138	3
Black slate, ...	13	0	151	3
Coal, 2d vein, ...	2	6	153	9

	Thickness. Ft.	Thickness. In.	Depth to Bottom. Ft.	Depth to Bottom. In.
Horseback,	1	4	155	1
Fire-clay,	6	0	161	1
Light soapstone,	3	0	164	1
Sandy shale,	6	0	170	1
Soapstone,	9	0	179	1
Dark soapstone,	58	0	237	1
Black slate,	2	0	239	1
Gray soapstone,	12	0	251	1
Black slate,	4	6	255	7
Light slate,	4	0	259	7
Sandy shale and lime,	4	0	263	7
Sandstone,	4	0	267	7
Fire-clay,	4	6	272	1
Dark soapstone,	34	0	306	1
Black slate,	5	0	311	1
Dark soapstone,	18	0	329	1
Coal, 3d vein,	3	0	332	1
Horseback,	0	9	332	10
Fire clay,	6	0	338	10
Dark slate,	7	0	345	10
Limestone and soapstone,	4	0	349	10
Sandstone,	4	0	353	10
Dark soapstone,	4	0	357	10
Blue soapstone,	4	0	361	10
Fire-clay,	4	0	365	10
Sandy gray rock,	6	0	371	10
Lime and sandstone,	16	0	387	10
Blue slate,	15	0	402	10
Sandstone,	5	0	407	10
Soapstone,	5	0	412	10

The depth given in the record of Mr. M. Rafter's notes shows No. 3 vein to be 332 feet 1 inch below the surface. The depth at which this seam was struck in the different shafts was: In No. 1, 345 feet; in No. 2, 358 feet; and in No. 3, 454 feet.

Improvements.—W. S. Ayres, of Hazleton, Pa., in his paper on "The New Breaker at the Cranberry Coal-Mine,"* observes that, in many cases, a complete destruction of plant proves to be a benefit to the operator. This statement is profoundly true. If the operator has the means to start anew, such a destruction is his opportunity; and of such an opportunity advantage was evidently taken by Messrs. A. Pardee & Co. in the case described by Mr. Ayres.

Shaft No. 1 of the Spring Valley Coal Co. met with a simi-

* *Trans.*, xxviii., 293.

lar disaster, and an equally lamentable loss; and, acting under the advice of its able manager, S. M. Dalzell, and with the approval of the president, Mr. M. H. Taylor, of Erie, Pa., the Company took the same view as the Messrs. Pardee, and has made this mine, for the cheap handling of coal and for safety, second to none in Illinois.

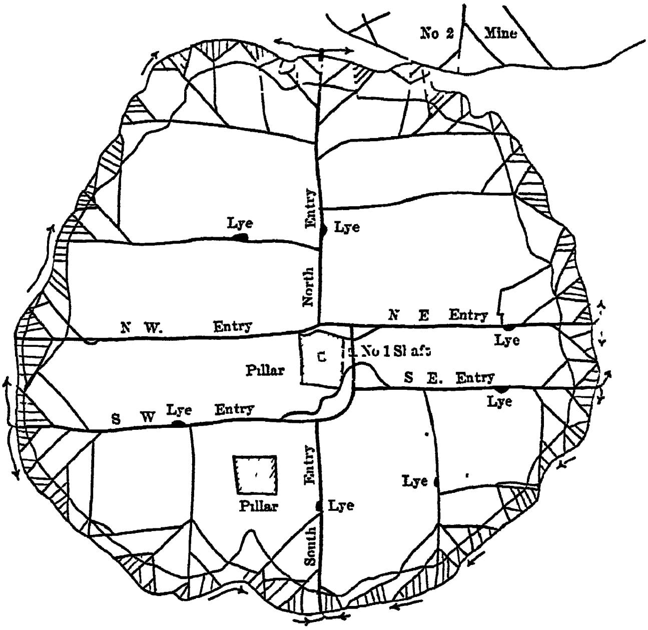
During the fall of 1894 the tower of No. 1 shaft caught fire. The falling embers from the burning tower ignited the woodwork at the bottom of the shaft, and the fire extended thence into the workings. Strenuous and constant efforts, extending over many months, were made to put out the fire, and to resume operations from this center, but the shaft had been so completely ruined that the management finally decided to abandon this site for hoisting, and to select a new location. Thus it came about that the present shaft was sunk, and it was this catastrophe which created the conditions and explains the improvements constituting the subject of the present paper. The new shaft is situated about 244 feet N.E. of the old one. Fig. 8 shows the surface-plant of No. 1, as completed.

Survey.—The site having been selected, a survey was made, so that operations could be commenced simultaneously underground and on the surface. This first survey of the shaft was made by Messrs. L. Gluck (the writer's predecessor), the resident engineer, and Mr. Merrick, engineer of the Chicago and Northwestern Railroad. When the writer took charge, the location of the shaft had been decided upon, and it was being sunk; some of the plans had been made, and operations were in progress.

The Old Shaft.—Fig. 4 is a section showing the condition at the bottom of this shaft after the fire. The line circumscribing the shaft indicates the ground which had given way, and which it was necessary to secure. It appears that the ground had given way from the bottom of the shaft to the middle seam, a distance of about 178 feet 4 inches. Though I was not here at the time, I infer that the fire commenced on the left side, and burned away the supports of the timbering on that side, leaving the right intact.

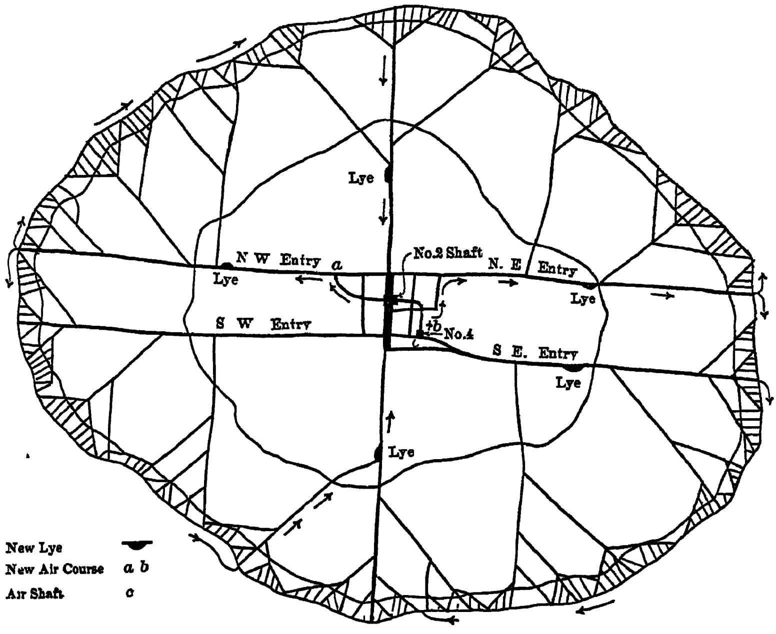
The best method to recover this shaft was suggested in *The Colliery Engineer* as a problem for solution, and some good ideas were furnished in reply to this inquiry. If the fire had not revived, some of these suggestions would probably have been tried;

FIG. 1.



PLAN OF NO. 1. WORKINGS, SPRING VALLEY MINES.

FIG. 2.



PLAN OF NO. 2. WORKINGS, SPRING VALLEY MINES.

but, fortunately for the Company, the whole project of making this shaft of further service was abandoned, and steps were taken at once to smother the fire.

The New Shaft.—The new shaft, like all the Company's shafts, is 17 by 8.5 feet in size. In having this uniformity of size there is a decided advantage. It requires but one set of duplicates to be kept in stock at the machine-shop for use in case of accident to any of the parts concerned. The chief machinist, Mr. Halladay, keeps a standard measurement of all important parts of the mine equipment, so that, when a breakage is reported, steps can be taken at once, from his notes, for the necessary repairs. The machine-shop is connected by telephone with the office and the mines, so that very little time expires after the breakage before the machinist is informed. The machine-shop is 68.35 feet long and 60.05 feet wide, and contains the necessary plant for the demands of a large colliery operation.

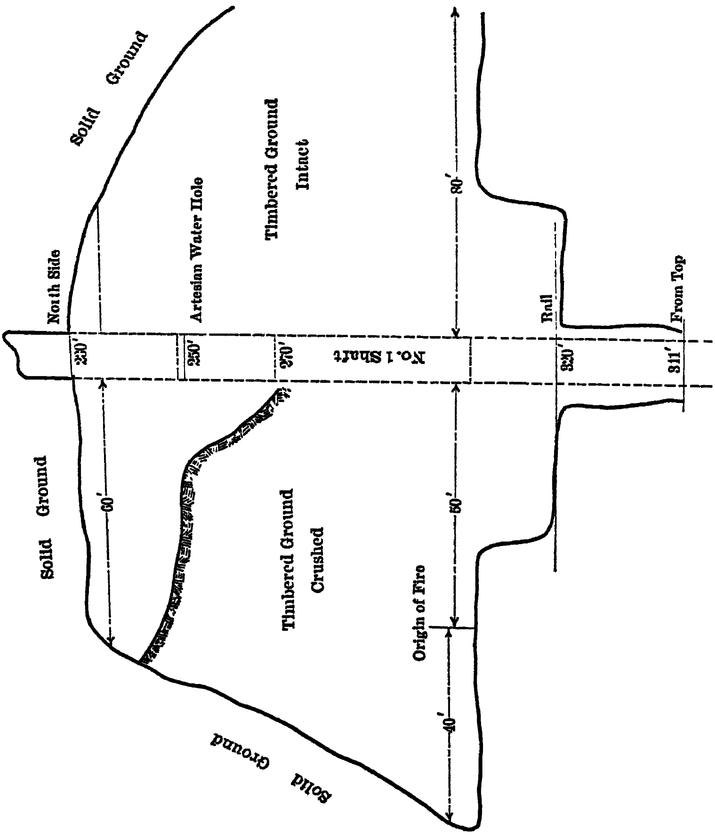
All the shaft-guides are 50-pound steel rails, and they are a great improvement over the old wooden guides, which were continually wearing out and causing delay.

The top of the shaft, outside of the shaft-timbering, is surrounded by a 2-foot wall, which goes down to bed-rock. Those acquainted with the topography of this field know that the ground is, in many places, covered with a glacial deposit ranging from a few feet to 20 and 30 feet deep. In this place we found bed-rock about 10 feet down. The character of the wall is shown in Fig. 9. The person in the foreground is Mr. S. M. Dalzell. This was our foundation for the steel tower mentioned below, and it was made of extra strength under the places where the posts of the tower were to rest.

The cap-stones, partially shown in the figure, were furnished by the Joliet Stone Co., with the holes already bored for the bolts of the tower. These bolts are embedded 9 feet 9 inches in the masonry. They have loop-ends, and through these loops were placed 28-pound rails about 6 feet long. At a point just above drainage-level a link-drain was made, so that the shaft is kept quite free from surface-water.

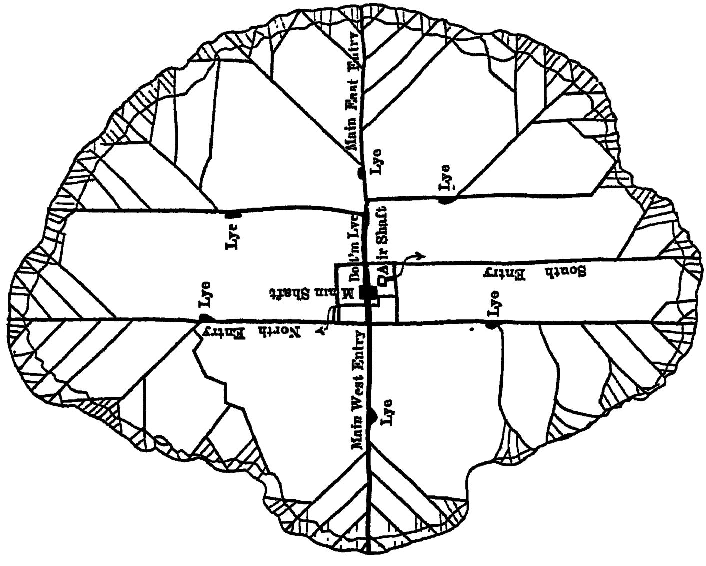
The shaft-timbers are of 6 by 8-inch pine. At every 9 feet, or thereabouts, a "horned set" was placed, to avoid displacement of the timber. In sinking shafts, this putting in of a

FIG. 4.



SECTION AT BOTTOM OF NO. 1 SHAFT, SPRING VALLEY CO., AFTER FIRE.

FIG. 3.

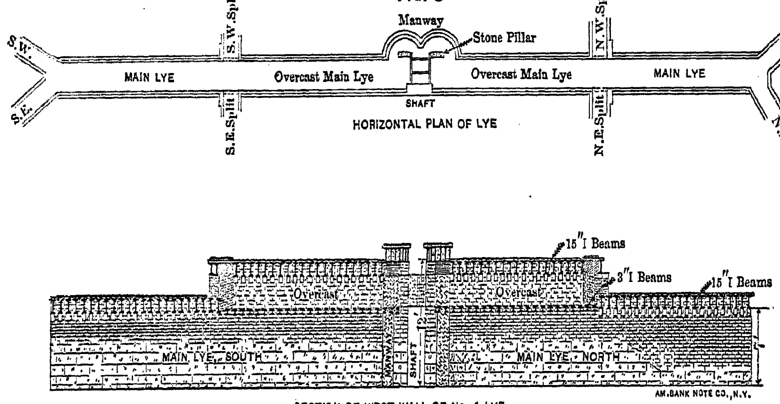


PLAN OF NO. 3. WORKINGS, SPRING VALLEY MINES.

horned set is often disregarded, and it may consequently happen that, when a set breaks, the whole shaft is in danger of collapsing. This danger is as imminent in sinking as at any other time; for there is no weight to bind the sets together.

The bottom of the shaft is shown in Fig 5.* It stands on 15-inch I-beams, placed, for the first 8 feet, about 12 feet above stops. On the west side of the shaft is a passage for crossing from one side to the other. This is also lined with masonry. The beams close to the shaft are spaced 2 feet apart, and two of them are 22 feet long; so that, in referring to the bottom of

FIG. 5



PLAN AND SECTION AT BOTTOM OF NEW SHAFT.

the shaft, we say it rests on two pairs of I-beams spaced 2 feet apart; after this the spacing is 4 feet.

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* The word "Lye," appearing in this figure, and in the text of this paper, may require some explanation for those who know only its English definition as a railway-siding. It is the same as the "double-parting" of Ohio collieries, namely, the underground space where coal is gathered by the "inside trams" to be hauled out by the "outside trams." The "bottom lye" is the station where the coal is collected for hoisting.

The usual way of making a lye has been to enlarge an entry, for the purpose, to about 14 feet in width, necessitating heavy and expensive timbering, and large cost for its maintenance. A more economical method, which we have adopted, is to utilize an abandoned "room," making what is called a "blind," instead of an "open" lye, *i.e.*, providing for the uninterrupted passage of mules and men, loaded cars and "empties," without enlarging any one passage for the purpose. However arranged, the lyes should always give plenty of room for passage, so that there may be no stoppage in transportation. The loss of fifteen minutes may mean ten tons of coal in daily capacity. The great (and open) secret of a large output of coal is in the avoidance of small leakages by delay throughout the mine; and a weak point which will bear watching is the lye.

Order of Development.—The order in which the work proceeded can be better appreciated upon examining Fig. 14, which is a horizontal plan of the bottom as it now stands.

The place where the main lye was commenced is shown by the letter A. It must be remembered that, while this work was in progress, a partially subdued fire was smouldering within a short distance, and, although every precaution had been taken to confine it within given limits, we were all aware that there was a possibility of its forcing its barriers. Indeed this danger became apparent when we found that the heat at the brick-stopping north of the old shaft was rapidly rising, and that the fire appeared to be forcing itself along the black shale above the timber. It was this fact that caused us to put in the three additional brick-stoppings on the north, and to make the circuit in the course of the air from H through G to F.

These stoppings were made of brick, 3 feet thick at the bottom, and 2 feet and 1.5 foot at the top. The bottom rests on the sandstone below the coal, and the top extends well into the rock above the black shale. In most of the stoppings a closed entrance has been left, and a 2-inch gas-pipe inserted; and all these pipes have been arranged in such a manner that, if necessary, any part of the old workings can be subjected to the injection of water sufficient to extinguish a fire of considerable strength and magnitude. At present, negotiations are in progress with the object of supplying No. 1 Shaft with the city water.

At a point on the main level, north from the old shaft, there is a small stream of water flowing from the old workings, which, during the time we are describing, was nearly at boiling-point. Now it is not over 70 degrees F. It is evident that the fire in the old shaft, if not entirely extinguished, has been so far subdued that it has ceased to be a source of anxiety.

Every entry deemed to have any connection with the old mine was closely dust-gobbed. If the ground was at all broken, the entry was opened until close ground was found for the dust-packing. The principal reason for making the main haulage along O, P, Q, was to keep the air-current well to the south of the seat of the fire. The first plan was to conduct the air up 1 and 2. The plan subsequently adopted, however, served an important object by reducing the grade from O to P. The

grade to the old shaft was the cause of a great deal of annoyance, loss of time, and danger to life and limb. The dip of the seam is to the N.E.; and by forming the irregular semicircle described, this grade was reduced, so that No. 1, though located at some disadvantage in this respect, now compares favorably with its more convenient sister-mines, Nos. 2, 3 and 4.

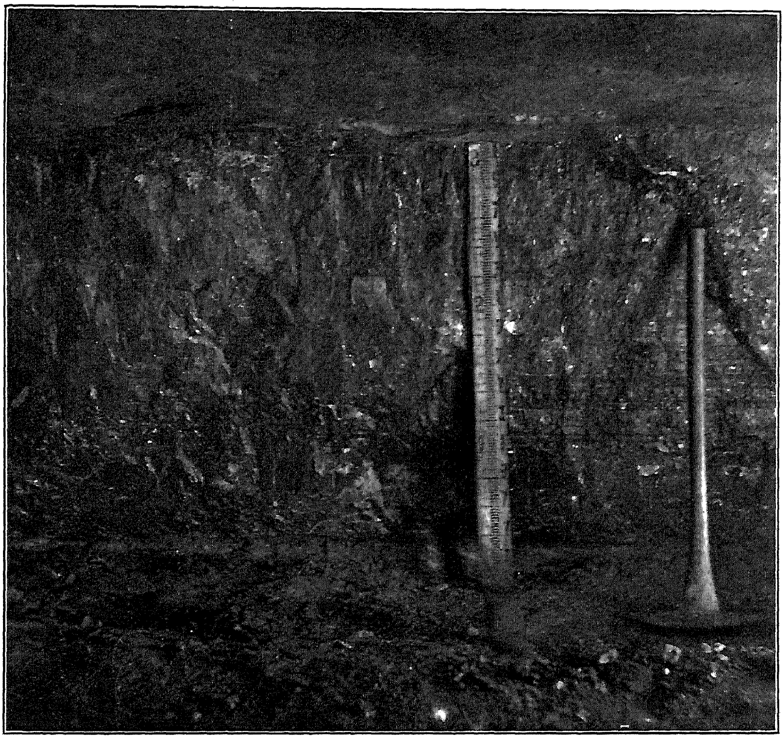
The Main Lye.—The main lye is 385.08 feet long; 178.26 feet on the north, and 206.82 feet on the south side. The roof is 7 feet above rail, and the gangway is 14 feet wide from wall to wall. Fig. 5 shows one wall, and Fig. 10 shows the I-beams, forming the roof, and resting on the cap-stones. These I-beams, with the exception of those otherwise specified, are all 15-inch beams, weighing 50 pounds per foot, and made to sustain 26.9 tons (safe load, uniformly distributed) each. They are spaced 4 feet apart, and rest on cap-stones 9 by 18 by 12 inches in size.

It will be observed that part of the wall is brick and part stone. It was considered that to handle stone where staging was necessary would make the cost of the wall as great as that of brick, while brick could be used to a much greater advantage. So stone was used for the foundation only. We could get this very cheap, there being a strong outcrop of good limestone on the property, situated a little over a mile from the shaft. The stone was put on the open railroad-cars at $13 a car, flush loading, or, say, 20 tons.

We used the Utica cement and common-sized brick, which answered the purpose remarkably well. The stability of the structure was clearly demonstrated by the following tests. After the bottom had been completed, I chiseled in the I-beams grooves for drop-lines, which were located two on each side of the shaft, in a straight line, established with the transit. About a month later I took the transit down again and placed it as before, so as to cut the line on the north end as well as the center-lines. Allowing for all combinations of movements helping to bring this about, the result proved that the structure could not have suffered any marked movement.

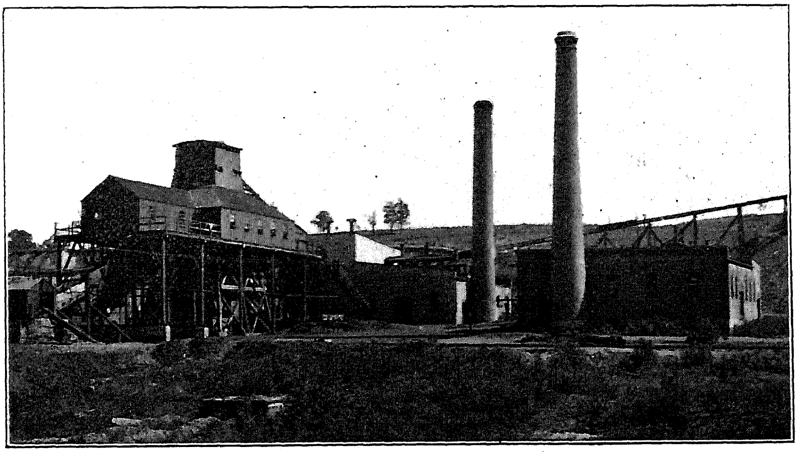
The Overcast.—The overcast, as shown in Fig. 5, enters from the west side of the shaft, and is carried above the lye to the point shown on the plan, splitting at about 100 feet north and south of the shaft. Where the split is made, the brick is

FIG. 6.



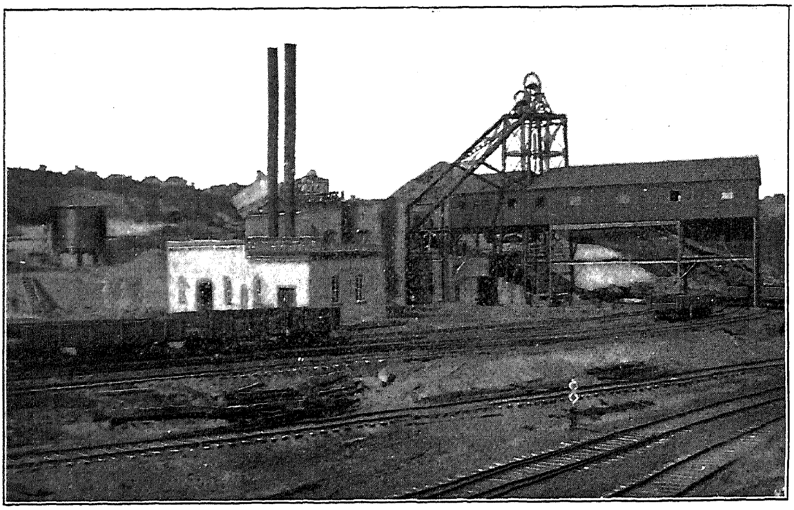
VIEW OF NO. 3 SEAM

FIG. 7.



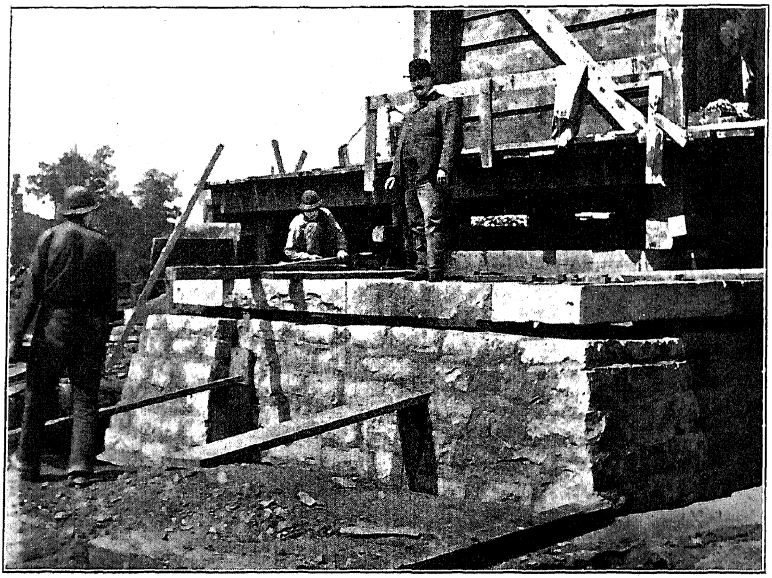
SURFACE-PLANT AT NO. 4.

FIG. 8.



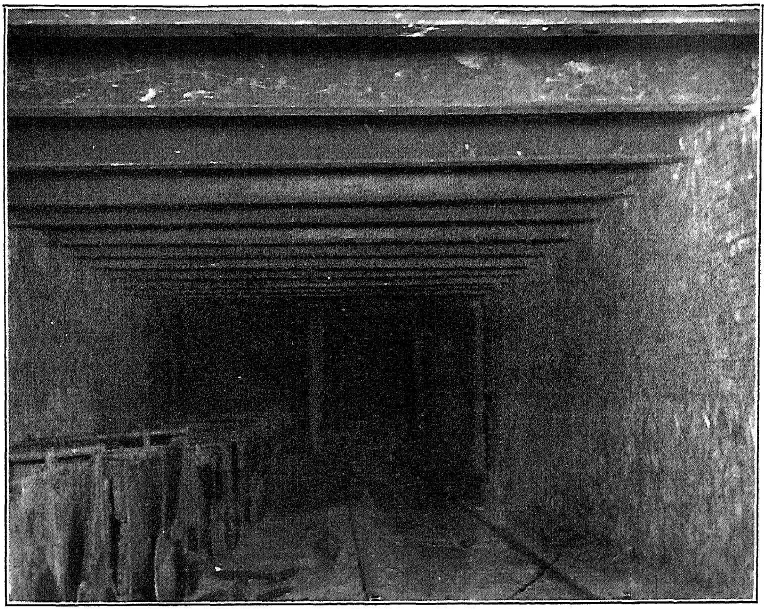
SURFACE PLANT NO. 1, COMPLETED

FIG. 9.



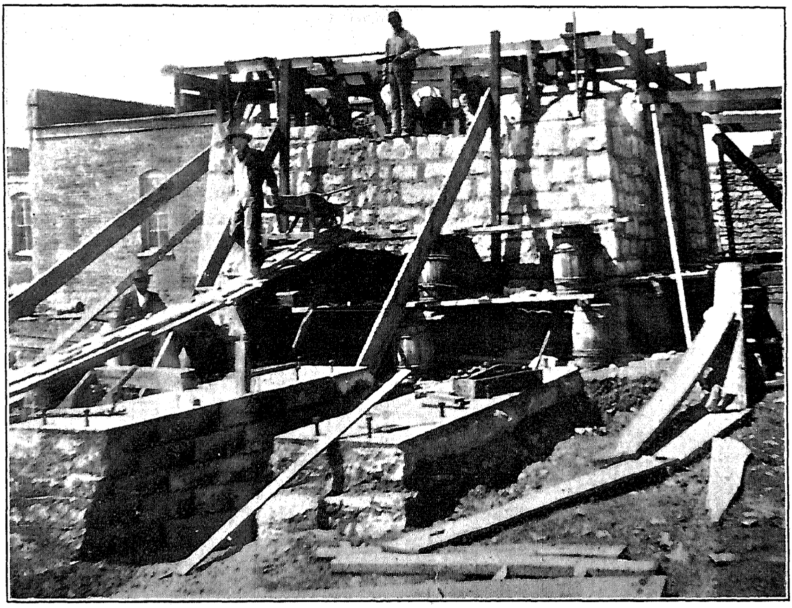
FOUNDATION-WALL STEEL TOWER

FIG. 10.



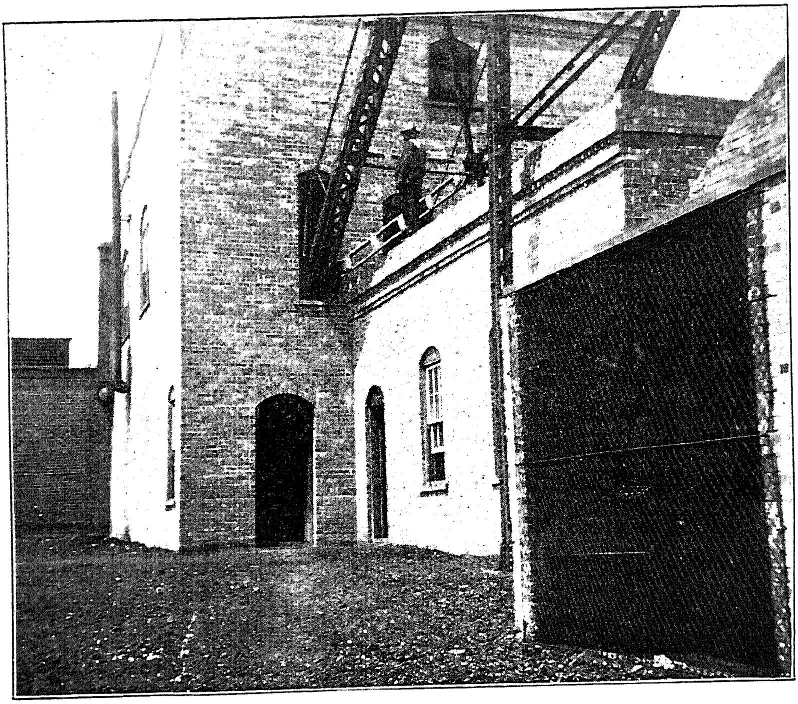
UNDERGROUND VIEW OF LYE.

FIG. 11.



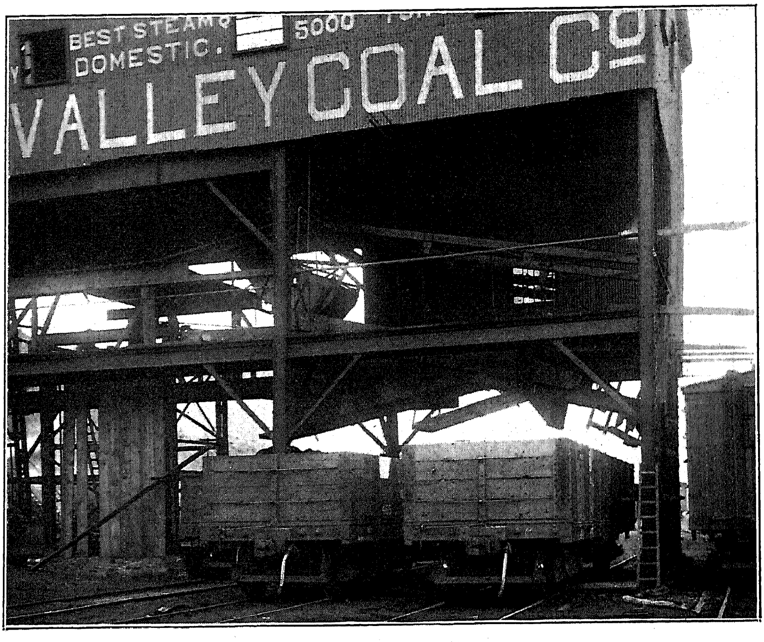
FOUNDATIONS OF ENGINE-HOUSE.

Fig. 12.



Engine- and Fan-House.

Fig. 13.

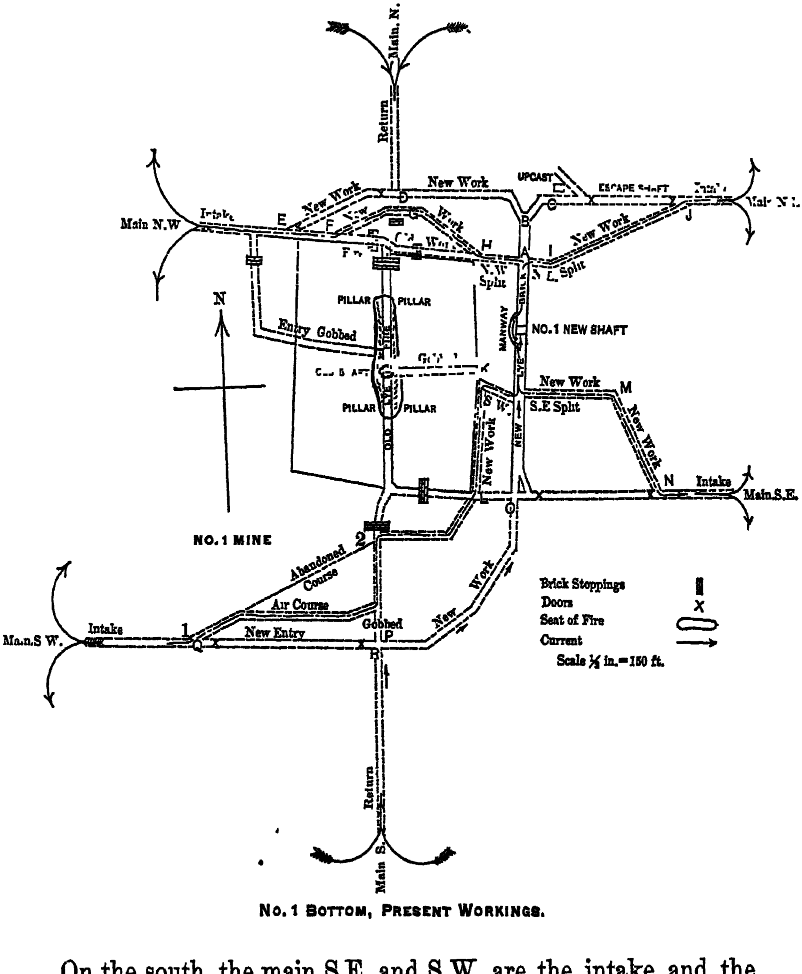


Shaker-Screens

carried, as shown, for some distance into the air-course, and the roof is covered with 60-pound rails.

The route of the air-current for the north side goes up the main N.E. and the main N.W., returning on the main N. and escaping up the main shaft and escape-shaft, shown in Fig. 14.

FIG. 14



No. 1 BOTTOM, PRESENT WORKINGS.

On the south, the main S.E. and S.W. are the intake and the main S. the return, going by P, O, to the hoisting-shaft. The walls, from the shaft to the splits, are made 10 feet 6 inches high, so that the air-course may be 7 feet above the rail. At 7 feet above the rail, 3-inch I-beams, 15 feet long, were placed; and on these were laid sheets of $\frac{3}{16}$-inch boiler-iron riveted

together, and made perfectly air-tight. This gave an area of 3x14 = 42 square feet for the air-course.

This overcast has one feature that causes some little inconvenience. Namely, particularly in winter, the condensation of the warm air from the return causes a continual dripping, and at times a mist that is not at all pleasant. At a very small cost, however, this can be partially improved, particularly on the north side, where it is most inconvenient, by diverting the return-course in the direction of the escape-shaft.

In all the work, timber was used as little as possible. The covering of the I-beams, however, was made of 3-inch oak plank.

In laying out the new shaft-bottom, provision had to be made on the north and south for a loaded trip to be held between the check-doors, the distance between the doors being 180 feet.

The bottom as it now stands is fire-proof. Mr. Dalzell was particularly anxious that no unnecessary timber, or any other substance that would take fire, should be put in.

This bottom at present lacks electric light. If lighted up, it would present a very imposing appearance.

Surface-work.—Simultaneously with the developments underground, excavations were in progress on the surface.

Fig. 11 shows the foundation of the hoisting-engine, and Fig. 12 the finished structure, containing engine and fan.

Foundations of the Engine-House.—The foundations rest on a blue solid clay, about nine feet below the level of the shaft-timber, where the pillars of the tower rest. On this clay we commenced to build. The masonry of the hoisting-engine was built solid in front. The solid masonry extends 10 feet back, and the two pillars upon which the cylinders rest are 16 feet thick at the bottom. The height of the cap-stone of the engine above the shaft-timber is 13 feet.

Joliet stone was used, with Utica cement for binding. As shown in Fig. 11, we first had a templet made, and this was elevated to the proper position, with all the bolts boxed and suspended thereto. We took our centers with the transit. The bolts for the pedestal of the batter-post of the tower were put in as we came up with the masonry. They were 4 feet long, with a loop on the end, through which heavy rails

were put and well secured. The figure shows also the foundation of the fan-engine and the fan proper. It will be observed that all the work on the fan is of brick.

In laying the foundations for the tower, the excavations for the pillars were made 6 feet deep. The masonry was 28 by 30 inches at the top, battering to 4 by 5 feet at the bottom. The bolts were 6 feet deep, and were tied to the stone-work with rails, as before described.

The foundation of the car-loader was made by driving 16-foot piles 9 inches square on the smaller end, placed 2 feet apart from center to center.

The Tower and Transfer-Table.—The top of the tower is braced with steel inclined framework, extending to the foundation of the winding-drum, and is supported by columns extending to the ground below.

A railing and stairway are provided on the inclined bracing, for use in reaching the head-sheaves. The building is braced transversely and longitudinally by both horizontal and vertical diagonal rods, to permit vibration due to hoisting, or the movements of the cars on the tipple-floors. Heavy bracing is also provided for the cage-guides, and under the cage are rests to resist the shock due to the landing of the heavy-loaded cage, when it reaches the top.

The manner in which the cars are moved may be described as follows: When either cage, the right one, for example, reaches the top with a loaded car, an empty car is already in position on the right transfer-table, immediately behind the cage. The tracks on the transfer-table and those of the cage are directly in line with the tracks leading to the tipple.

There is a Ramsay pusher directly in the rear of the empty car; and as soon as the cage is brought to rest on the cage-rest steam is let into the pusher-cylinder. The piston moves forward and pushes the empty car against the loaded one, which is thus driven off the cage, and the empty car takes its place, ready to descend.

This arrangement is duplicated for the other cage, which is now at the bottom of the shaft, and the transfer-table, which is at the outer left-hand side of the building, ready to receive an empty car on its return from the tipple. The loaded car which has just been pushed off the cage is moved forward until it

passes onto the tipple and is dumped. It then passes over the tipple and is switched onto one of the return-tracks, which pass to the rear on each side of the cage-frame. The empty car moves along the track until it passes onto the transfer-table, which is now on its lower and outer position, near the side of the building. As already stated, the transfer-tables are in duplicate, one on each side of the center-line of the building, which is parallel to the tracks leading from the cage to the tipples.

The transfer-tables move on tracks at right angles to the above-mentioned center-lines. When either transfer-table is in the position first described, with the empty car, which is ready to be pushed to the cage, it is at an elevation of about 3 feet above, and at a distance of about 12 feet inward, towards the center of the building, from where it received the empty car from the return-tracks. The tracks on which the transfer-tables move are therefore linked upward, from each side of the building, towards the center. The transfer-tables alternate in their movements, so that when the right one is at the top with an empty car, in position to be pushed onto the right-hand cage, the left-hand table is at the bottom of its incline, ready to receive an empty car from the left-hand return-track.

Both the tables are operated by a steam-cylinder, underneath the transfer-tracks, which has a through-going piston-rod. A continuous-wire cable, to which the transfer-tracks are attached, runs around a sheave at each side of the building, returning underneath towards the center, and has its ends attached respectively to the opposite ends of the through-going piston-rod. As the piston moves from one end of the cylinder to the other, the transfer-tables are moved—the right one, say, from its lower position behind the right cage, while the left one is moved behind the left-hand cage, down to connect with the left return-track.

The tracks on the tipple-floor are laid on a slight incline, so that gravity will aid in moving them. The total amount of incline from the cage-rest here, forward over the tipples, and back along the return-tracks to the transfer-tables, is the amount that the transfer-tables have to be inclined.

The Ramsay pusher does its work splendidly, and no loss of time has occurred owing to it; but it certainly materially les-

sens the life of the cars. The tower shows but slight vibration from the winding or from the dumping. But recently we have put in a shaker-screen, and of this the tower feels the effect. This one criticism, however, covers all our objections. I would heartily recommend the plant, as it stands, to anyone intending to put in a steel tower.

The Capell Fan.—The fan-wheel for this plant is 12.5 feet in diameter and 5 feet wide. It is set on a brick foundation, and the side is covered with a curved roof of steel. It is driven by a belt from a pair of horizontal engines of 14- by 24-inch cylinders. The engine-pulley is 9 feet and the fan-pulley 3½ feet in diameter. The fan-shaft is 9.5 inches in diameter, 15 feet long, with three bearings, each 20 inches long, one of them being outside of the pulley.

The inlet of the fan, which is on one side only, is 7 feet 9 inches in diameter, and receives the fresh air from the atmosphere, which is whirled to the pounder and thrown off at a considerable pressure into a steel-lined drift, connected with the top of the air-compartment of the shaft. By an arrangement of doors the fan can be changed in less than a minute so as to exhaust the air from the mine. The whole structure is of iron, steel and brick, and is therefore incombustible.

The fan-wheel, with its bearings, weighs over 9 tons, and is riveted together in a most substantial manner. It has plate-wings; the outer ones bending away from the edge of the inlet and opening to the perimeter—the tips falling back from the direction of rotation like those of a Murphy fan—but it has, in addition to these outer wings, an inner set, extending from the edge of the inlet-opening to near the center of the fan, and joined to the outer wings by a strong steel top, called a bridge-plate, by a double row of rivets. Each of these inner wings carries on the outer end a center-plate called a scoop, projecting about 6 inches beyond the inlet-surface. These scoops have their concave sides towards the direction of rotation.

Firmly riveted to a flanged hub of cast-iron, keyed upon the shaft, is a disk of steel ⅜-inch thick and of the full diameter of the fan (12.5 feet). To this disk are riveted the wings of the vanes, the other members staying and framing them together. These inner wings are not placed parallel to the axis of the fan, but at angles subtended with the axis, varying in each case

with the particular mine for which it is built. The scoops are also adapted to the required volume, and, together with the oblique inner wings, draw air, screw-propeller fashion; and, the air once there, the only way of egress is by the tips of the outer wings.

The peculiar advantage claimed for the Capell fan is, that it takes hold of the air in a most positive manner, and will not let it slip. Other advantages claimed are strength and durability, large output for small engine-power, and smallness of space occupied. The fan is the invention of the Rev. E. M. Capell, Rector of Passenham, Stoney Stafford, England, and William Clifford, M.E., Pittsburgh, Pa., is the sole licensee for the United States.

Fan Engine-House.—This engine-house (see Fig. 12) is 51 feet long, 19 feet wide and 12 feet high. The walls are of brick. The roof is practically flat, but with a 2-foot incline, covered with composition and gravel roofing. On the south side, where the south wall abuts against the fan, there is a lower basement for the pump which supplies the tank. The dimensions given afford sufficient room for all purposes—smaller ones would cramp the arrangement. In building our new fan-house at No. 4 we duplicated this building as closely as possible.

The engine has been described. I may add, however, that it is a horizontal engine, made by Bullock, of Chicago.

The Hoisting-Engine and Building.—The engine-house is 40.6 feet long, 32 feet wide and 30 feet high.

The engine was made by Bullock & Co., Chicago, and used for hoisting from the old shaft. It is a first-motion, double-cylinder, 22 by 8 inches, with an 8-foot wood-lagged drum, provided with a steam-brake, steam-reverse, and brake-spider 7 feet 5 inches by 12 inches wide. The main steam-pipe is 7 inches in diameter to the throttle, and to the cylinders 6 inches. The engine-frame, bearing and pedestal weigh 12,500 pounds each. The cylinders weigh 7000 pounds each; the drum, 16,500 pounds; the shaft and two disks, 11,500 pounds. The diameter of the shaft is 11 inches; that of the piston-rods, $3\frac{5}{16}$ inches; that of the crank-pin, $6\frac{1}{2}$ inches.

The Boiler-House.—The building is 46 feet long and 39 feet wide. At present it contains two boilers. These are tubu-

lar boilers, 66 inches in diameter and 25 feet long, made by the Union Iron Works.

I should mention here that the number of boilers on the whole property in use is 27 (eight of which are at No. 1).

Shaker-Screens.—The shaker-screens (Fig. 13) were built by the Link Belt Machinery Co. The upper screen is 24 feet long by 6 feet wide, having approximately 90 square feet of 6-inch perforated plate, 0.25 inch thick, on its upper level, and 93 square feet of 1-inch perforated plate, $\frac{3}{16}$ inch thick, on its lower level. The screen is built up of frame-work of 3- by 3-inch angles, with $\frac{3}{16}$-inch side-plates and stiffening angles, tees and straps.

One lower screen is approximately 31 feet long by 6 feet wide. This screen will have approximately 90 square feet of $\frac{3}{4}$-inch perforated plate, No. 10 gauge. Beneath this perforated plate there will be suspended an apron, approximately 17 feet long, for delivering the slack-coal which passes through the $\frac{3}{4}$-inch holes to cars on the inner track. The apron is suspended from this screen, and has its sides closed in with steel plate of No. 16 gauge. At the beginning of this apron there is a valve, which, when opened, will permit the nut-coal to mix with the slack-coal on the inner track. This screen is provided with two other aprons, one for the nut-coal and one for the egg-coal, with a valve for each. The outer end of this screen is provided with a Link Belt Universal loading apron, designed to deliver coal on the outer track to either high or low cars. The sizes and combination of sizes of coal furnished are as follows:

1. Mine run (coal as mined, not screened).
2. Lump;—egg;—nut;—slack.
3. Lump;—egg and nut;—slack.
4. Lump;—egg;—nut and slack.
5. Lump and egg;—nut;—slack.
6. Lump, egg and nut;—slack.

The box is made of steel, and is operated by a steam-cylinder; and the scales for it are equipped with a dial quick-weighing arrangement.

Double Cages.—These cages are now to be put in. The capacity of the shaft has been reached. The circle underground is continually getting larger, and more room is made for a greater number of men. The question now before the manager is, How can the output be increased? As there is

always coal ready at the bottom of the shaft, we cannot improve in that respect. No stoppage is to be observed on the surface, so we must look to the shaft. At present we are able to hoist 3 cages per minute (the average weight in a car of coal being 2600 pounds); but perhaps 5 cars in 1 minute and 58 seconds is nearer the rate of our average hoist.

We intend giving the double cages every chance, and trust with them to increase our output.

The improvements here described commenced with the sinking of the new shaft early in 1896. The putting in of the double-deck cages and shaker-screens, and putting in a new tank and supplying the boilers with city water, are the developments of this year. Electrical haulage and mining are being considered, and are to be looked forward to as the probabilities of the near future.

So well satisfied is the management with the outcome of these improvements at No. 1 that in the spring of 1897 I was instructed to give estimates and prepare plans for the remodeling of bottoms at Nos. 2, 3 and 4. Early in May operations were commenced, and similar arrangements were made at both these places with the exception that there was no overhead airway in either of the mines, and that at No. 2 the height from the bottom stops was only 9 feet. At No. 3 it is 12 feet. Also, at No. 2 and No. 3, in addition to the timber, the spaces between the I-beams for 12 feet were arched with brick, instead of being covered with rails.

During 1897 there were completed in No. 3, of this kind of lye, 77.60 feet on the east and 66 feet on the west; also, *in addition*, 16 feet of an arched air-course connecting the shaft with the main air-course, and a passage-way around the shaft.

At No. 2, 108.7 feet of lye on the north and 148 feet on the south were made in 1897.

This year (1898) estimates were made for a steel tower at No. 2, and the rearrangement of the bottom air-courses, and the placing of a Capell fan, at No. 4. All this work has been done; with the exception of the steel tower. The new air-courses made this year amounted to 951 feet. The overcast was made by building an 8-inch wall on the I-beams and covering it with flat pieces of iron about 6 inches apart, the space between being brick. The area is 48 square feet.

Mines Nos. 1 and 2 being connected, the distribution of the air is somewhat different from that of No. 1. There are only 3 splits. One goes southeast from No. 4, and returns on the south, where the two mines connect. The other split starts north and divides at the end of the new air-course made therein —one split going up on the northeast; the other going over the overcast and up the northwest; and both returning along the main north.

This year the addition to the lye was 121 feet. It is now finished, and being lit with electricity presents an imposing and pleasant appearance.

The problem at Nos. 2 and 3 was quite different from that at No. 1. At No. 1, the excavation was in solid rock, and the ground could be excavated to within a very little of the regular height for I-wall, beams and covering. At Nos. 2 and 3 it was necessary to take away, for a distance of 20 to 30 feet, the old timbering, which had over it, in some places, from 20 to 30 feet high of lagging. This required the greatest caution. The I-beams would at times fall short or exceed the desired space between, and in order to prevent a serious fall, much time and extra material would be used. In estimating a matter of this kind the engineer can only fall back on his experience, which alone can help him to give an approximate estimate.

The writer, having had a somewhat large experience in this kind of work, felt its value at this juncture; nevertheless, in submitting his estimates he recognized that a small accident, "the unforeseen," might upset them.

I am sorry that I cannot, without trespassing on the indulgence of the management, present more of the figures of labor and material than have been given in this paper. I shall, however, be pleased to answer any questions that will not commit me to a breach of confidence.

I desire to thank Mr. S. M. Dalzell, General Manager of the Spring Valley Coal Co., for the permission given me to make use of the data furnished.

The credit of these improvements belongs entirely to him, and came directly under his supervision.

I would acknowledge the receipt of a description of the fan and tower from Mr. Church, of Chicago, Engineer of the Pittsburgh Bridge Co., and extend to him and to Mr. Clifford, of Pittsburgh, Pa., my thanks for their courtesy.

The Rich Patch Iron Tract, Virginia.

BY H. M. CHANCE, PHILADELPHIA.

(New York Meeting, February, 1899.)

In the early part of 1898, I had occasion to make for the owners a professional examination of the Rich Patch tract; and, with their permission, I present in this paper, omitting the commercial portions of my report, those portions which may be valuable to future students of that region.

Location, Topography and Geology.

The Rich Patch tract comprises about 9000 acres, located about 3 miles west of Low Moor, on the Chesapeake and Ohio Railway, in Alleghany county, Va., and immediately adjoining the Low Moor property. In shape the tract is roughly quadrangular, being about 3 miles broad in a northerly and southerly direction, by about 6 miles long from east to west. Potts creek and Jackson river run along its northern boundary. It is drained by Hayes Gap run, Mill branch and Laurel creek, which flow north into Potts creek, and by Karnes creek, which flows northeasterly through the Low Moor property into Jackson river.

The topography of the tract is shown by the accompanying map (Fig. 1), and need not be described here. The valleys are cut down from 1000 to 1500 feet below the mountain summits, which generally reach an altitude of about 3000 feet above tide.

The geological structure of the district is indicated by the geological cross-sections shown in Figs. 2 and 3.

These sections show that the formations underlying the property extend from the Lower Silurian limestones up to the Devonian slates, including the numbers of the Paleozoic system of rocks as defined by the geological surveys of Virginia, Pennsylvania and New York, from No. II. to No. VIII.

No. IX. Old Red Sandstone, } Devonian.
No. VIII. Slates and Shales, }

No. VII. Oriskany Sandstone—*Ore.*
No. VI. Lower Helderberg Limestone.
No. V. Clinton Shales, etc.—"*fossil*" *ore-beds*,
No. IV. Sandstones—mountain forming,
No. III. Slates and Shales—Hudson River Group, Silurian.
No. II. Lower Silurian Limestones—valley forming,

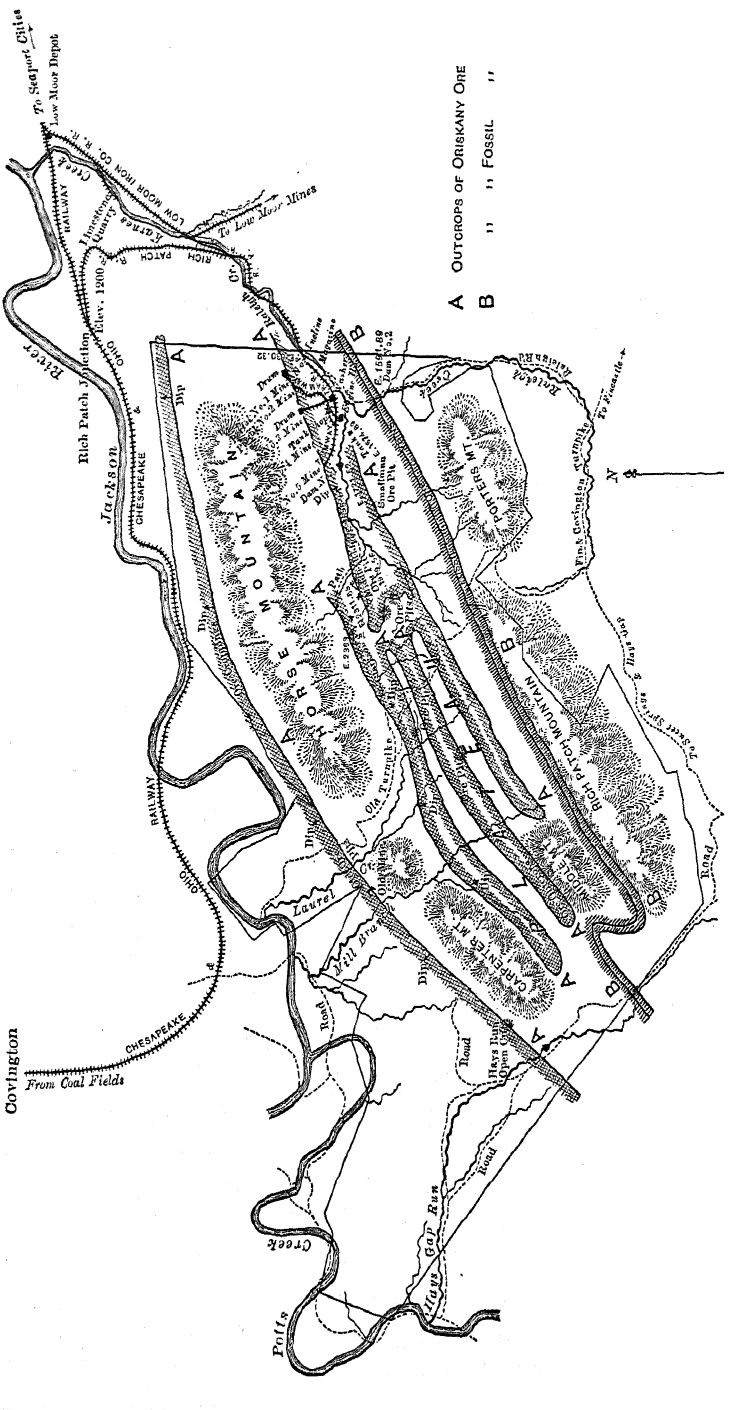
No. IV. forms the back part of Rich Patch Mountain.
No. II. is the underlying formation of Rich Patch Valley.
Nos. V., VI., VII. and VIII. occupy the valleys.

Ores.

The property produces two kinds of ore: red hematite, known as the "Fossil" ore, and brown hematite, known as the Oriskany ore.

Fossil-Ore.—This is the well-known ore of the Clinton formation, mined so largely in the vicinity of Birmingham, Alabama, and in many localities in the Appalachian chain, extending from New York to Alabama. In some localities in Alabama these fossil-ore beds attain a thickness of 20 feet or more—in Pennsylvania they rarely exceed 2 feet in thickness. They are true beds of sedimentary origin, and are as continuous and as persistent as a bed of limestone, sandstone or any other sedimentary rock, with this important qualification, that their value as iron-ore deposits depends upon the alteration which they have undergone, transforming them from calcareous to more or less ferruginous beds. On the Rich Patch tract two beds of fossil-ore have been opened at a number of points. In addition to these artificial exposures, these veins show a number of natural outcroppings. They range from 3 to 5 feet in thickness. Owing to the greater thickness of the brown hematite ores, these red-ore beds have been worked very little. While the quantity of this ore is very large, and the beds lie in position favorable to rapid and economical mining, the veins are so much smaller than the brown hematite ore-beds that they cannot be considered as of much importance at the present time, for certainly there will be no incentive to operate these veins on a large scale until the large brown hematite veins are practically exhausted.

FIG. 1.



THE RICH PATCH IRON TRACT, ALLEGHANY COUNTY, VIRGINIA.
Scale 1 inch = 7,425 feet.

The presence of these ores, however, constitutes an element of value, as they may be advantageously used as a mixture in small quantities with the softer brown ores for making special grades of pig-iron.

Brown Hematites.—The ores of this class upon the tract in question are the so-called "Oriskany" ores, occurring in close relation with the Oriskany sandstone, at the base of the Devonian or top of the Silurian epoch. This formation is not commonly ore-bearing; and although ore is occasionally found in this horizon at points scattered all the way from the State of New York to Alabama, it is only in Virginia that it presents a large and persistent series of iron-ore beds. These deposits are continuous, persistent, and remarkably uniform in character and thickness over large areas; and they lie everywhere conformable and parallel with the rocks in which they occur—differing essentially in this respect from the brown-hematite deposits of the Lower Silurian limestones, which constitute the principal deposits of such ores found throughout other portions of the Appalachian chain from New England to Alabama.

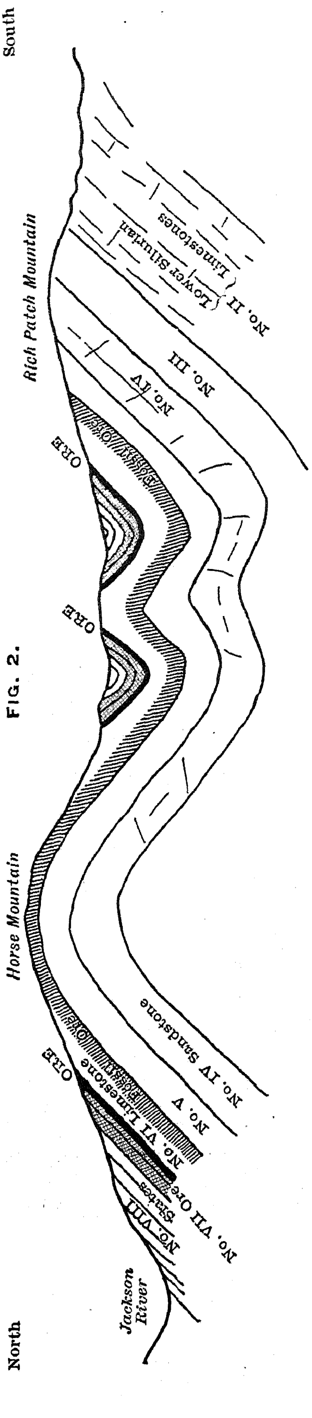
The ores of the Oriskany horizon are noted for the peculiarly soft and strong foundry-iron made from them by furnaces located in the district. They are usually richer in iron than the limestone or Potsdam ores of the Great Valley.

The Oriskany ores of Virginia reach their greatest development in the region in which the Rich Patch tract is situated; and, as will be seen, they are present in large amount upon that tract.

Genetically, they seem to be concentrations of iron-oxide resulting in a siliceous iron-ore. The extent and degree of this concentration, however, seem to have been exceptionally great in this part of Virginia only.

Two distinct beds of Oriskany brown-hematite ore have been opened upon this tract, but mining has been confined to the lower bed. The same may be said of the Low Moor property, immediately adjacent on the east, where two distinct beds have been opened and worked, the lower of which, being the thicker, is regarded as the principal vein, the overlying one being considered as a "rider" or sporadic deposit. It is evident, however, that this upper vein is continuous and persistent

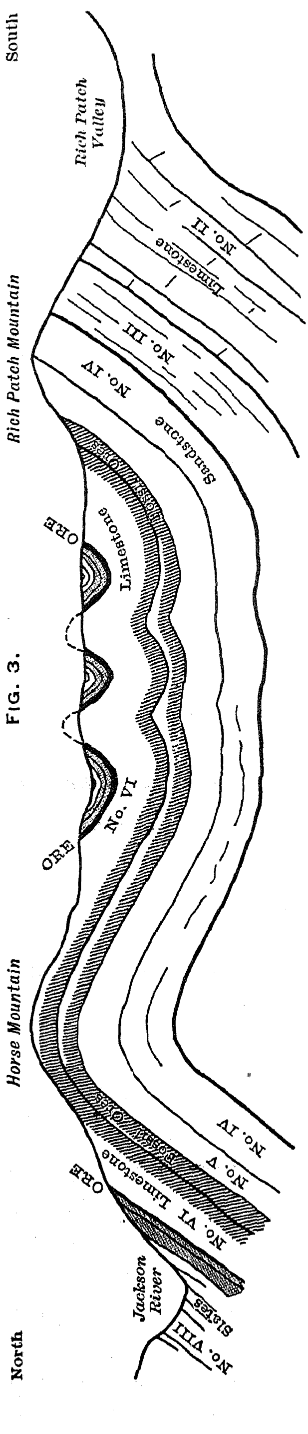
FIG. 2.



Cross-Section showing Structure at Low Moor Workings, near the East Line of Rich Patch Tract.

Scale 1 in. 2475 feet.

FIG. 3.



Cross-Section across Plateau showing three Ore-Basins, looking North East.

Scale 1 in. 2475 feet.

over a considerable area, and will yield a large quantity of ore.

Owing to the fact that the lower bed has been the only one from which ore has been mined upon the Rich Patch tract, there has been little development of the overlying bed, and nothing is known of this bed beyond the facts: (1) that it can be seen where it has been passed through by the tunnels driven for developing the main vein; (2) that it presents a number of natural outcrops; and (3) that its presence is evidenced by float-ore seen upon the surface at many points on the tract.

Owing to the meager developments upon the upper vein, its thickness cannot be accurately stated. In Tunnel No. 6 the vein is about 40 feet thick, and is separated from the lower vein by an interval of about 80 feet.

In the adjacent Low Moor workings the interval between the two veins varies considerably. In a left-hand drift swung off from Tunnel No. 6, and crossing the upper vein at an angle of 45° to 60°, this upper vein is of extraordinary thickness, the tunnel being in ore for a distance of 180 feet, and the interval between the two veins is quite small.

The foregoing embraces practically all that can be learned respecting the upper vein in this locality, but is sufficient to show plainly that it is second in importance only to the lower vein upon which the extensive workings and developments have been made.

The thickness of the lower ore-bed may be taken as averaging from 35 to 45 feet. It is not perfectly uniform. Occasionally a squeeze or "horse" pinches the vein down to 6, 8 or 10 feet, which diminished thickness may extend for a short distance, when the vein again expands to its normal size. But as an offset to these occasional pinches or thinning of the vein, it is subject to occasional enlargements, in which the thickness swells to 60 or 80 feet. These enlargements, like the pinched places, usually continue for a short distance, when the vein resumes its normal size. The lower vein extends throughout the property, as indicated by the lines of outcrops shown upon the map. It will be understood that these outcrop-lines are located as accurately as is possible without an instrumental survey, having been laid down on a map made from boundary-surveys, supplemented by some topographical work, so that, while not

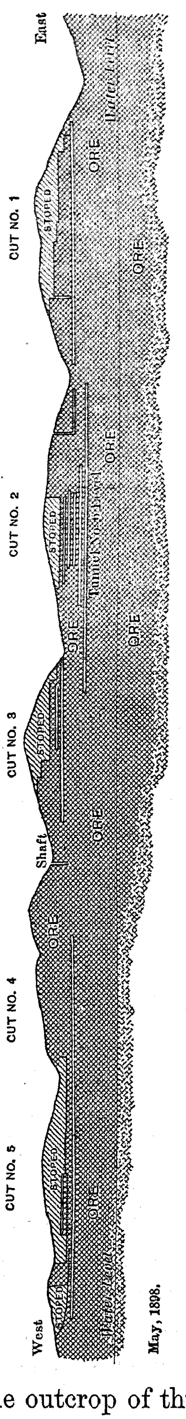


FIG. 4.

SECTION SHOWING WORKINGS ON THE ORISKANY BROWN HEMATITE ORE, BY THE RICH PATCH IRON COMPANY, ALLEGHANY COUNTY, VIRGINIA.

Scale 1 inch = 800 feet

mathematically exact, they are shown with sufficient accuracy for all practical purposes.

These outcrop-lines show that at the eastern end of the tract there is probably only one range or outcrop of the brown-hematite ore south of Horse mountain; but going westward about one mile from the eastern limit of the tract, a second range of ore is found. From this point to the extreme western edge of the property on Hayes run the intervening area contains three synclinal basins with a corresponding duplication of outcrop-lines.

The general structure of these synclinal basins, extending from the Low Moor workings on the east to Hayes run on the west, is similar, but the floors or axial lines of these synclinal troughs are rising rapidly toward the west, so that, while at the Low Moor workings the center or deepest portion of these troughs is not less than 400 feet (and possibly much deeper) below water-level, the center of these troughs at Hayes run is several hundred feet above water-level.

Quantity of Ore.—From the data here given, and with the aid of the map and geological cross-sections, it is evident that the quantity of ore contained in these brown-hematite beds is enormous.

We have, in the first place, a range of ore dipping to the north on the north side of Horse mountain, and extending east and west a distance of about 6½ miles, or, say, 32,000 feet. The outcrop of this vein lies high up on the flank of the moun-

tain, and the ore available above water-level is not less than 500 feet on the slope of the vein. The thickness of this vein may be conservatively estimated at 20 feet. On the south side of Horse mountain we have a similar range, 30,000 feet long, which may be estimated at 300 feet in depth and 30 feet in thickness. Similarly, on the north slope of Porter's and Rich Patch mountains we have a range about 20,000 feet long, which may be also estimated at 500 feet for depth of stoping-ground and an average of 30 feet in thickness.

Again, in the area between the head-waters of Clear creek (a branch of Karnes creek) and Hayes run, we have a duplication caused by the three minor synclinal folds running under, across and through this plateau for a distance of about 15,000 feet. The width of stoping-ground which may fairly be estimated in this plateau is more or less conjectural. It certainly is not less than 1000 feet, including the duplications on the four yet uncounted sides or dips of these minor flexures. It is entirely possible that owing to the shallow, flat form of these folds the stoping-ground may cover a very large part of the plateau.

To this quantity must be added whatever estimate may be made of the upper or overlying vein. Without going into the matter in detail, I should say that it would be safe to estimate the contents of this upper vein at not less than one-fourth of the amount contained in the lower vein.

Quality of Ore.—The quality of the Oriskany ore is best determined by the results obtained in furnace practice. These results indicate the quality of ore more safely than any series of analyses.

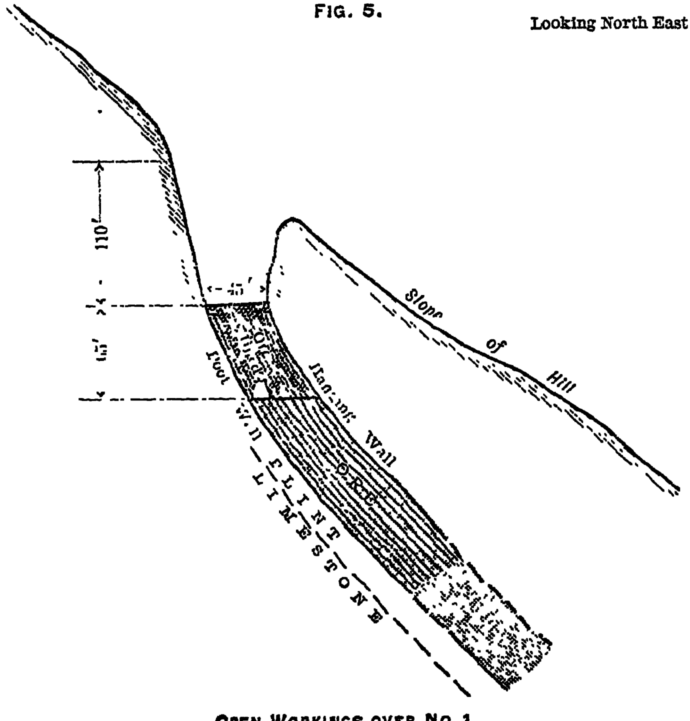
These brown-hematite ores show, by chemical analyses, metallic iron ranging from 42 or 43 per cent. up to 54 or 55 per cent. The average of such analyses may be taken at about 47 or 49 per cent. of metallic iron; and with more careful preparation of the ore the percentage of iron may be raised to about 50 per cent., and the silica percentage kept down to possibly 11 or 14 per cent. As mined and shipped under the present method of preparing the ore for shipment, the silica has ranged from 15 to 19 per cent., sometimes running somewhat higher, and occasionally somewhat lower, than these figures.

The phosphorus-contents will ordinarily range below 0.3 per cent., so that the pig-iron made from this ore carries less than 0.6 per cent. phosphorus.

The ore contains practically no sulphur; whatever sulphur is carried by the pig-iron made from these ores is derived from the coke used in smelting the ore; so there is no difficulty in keeping the sulphur below 0.05 per cent.; and an iron much lower in sulphur can easily be made from this ore when running on high-silicon pig.

The ore carries very little manganese—usually about one-half of 1 per cent.

FIG. 5.



OPEN WORKINGS OVER NO. 1.
Cut 560 feet long

The Buena Vista furnace, when running exclusively on this Rich Patch ore, produced a ton of pig-iron with an average consumption of 2.19 tons of ore. This, in my judgment, is the best measure of the iron contents of the ore, as shipped under present methods of preparing it for shipment.

Mining Development.

The practical development of this tract commenced in 1890, when a railroad was built connecting it with the Chesapeake and Ohio Railroad.

The workings extend through five hills, where the ore was first mined in open cuts, and these hills are known as Nos. 1, 2, 3, 4 and 5—No. 1 being furthest east and No. 5 at the west end of the developed area. Figs. 3, 4, 5, 6, 7 and 8 show the character and extent of the open-cut workings and indicate the underground workings, and their locality is indicated on the map (Fig. 1). These five hills are merely spurs projecting from the flank of Horse mountain; they are in reality merely what is left of a bench on the flank of the mountain, which has been cut or eroded by a number of ravines until the several hills stand out in quite bold relief.

The development extends for a distance of about 5000 feet along the bed, and throughout this distance it has been most thoroughly explored. The most recent development is the driving of a tunnel (known as No. 6) near the center of the developments, which taps the bed at a lower level and opens for extraction a very large quantity of ore.

At the point where these developments are made, it will be observed that there is only one range of the brown-hematite ore in the area south of Horse mountain. This is caused by a complete overturning of the formations, with probably some faulting of the measures on the south side of the Karnes creek valley. About a mile west of this point, however, the formations straighten up, and the normal structure continues from this point to its western boundary.

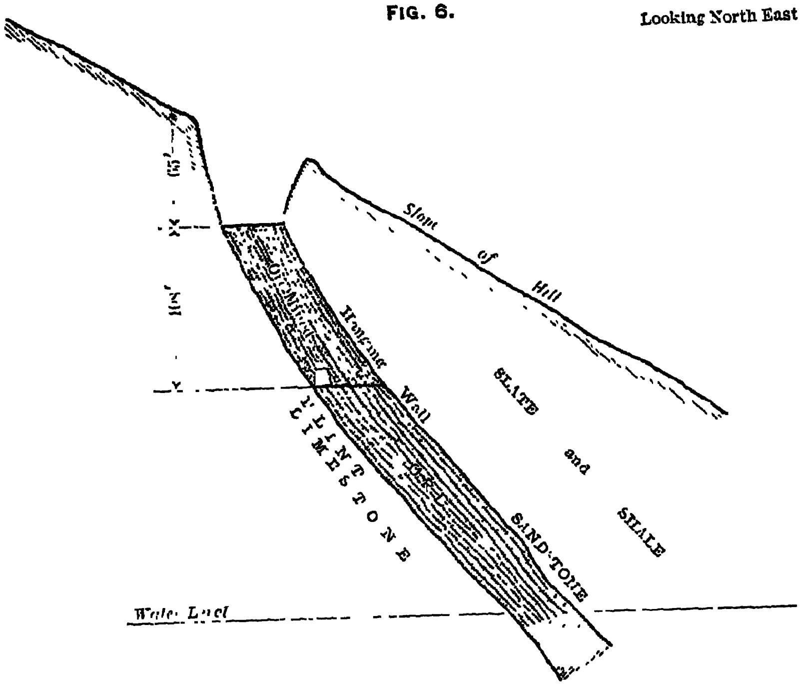
The lowest ore-levels—those of Tunnel No. 6 (Fig. 8) and under cut 5 (Fig. 7)—show almost unbroken bodies of solid ore. The vein is usually about 35 to 45 feet thick, with occasional thicker and thinner places.

In addition to the mine-developments and open cuts 1 to 5, inclusive, there are numerous prospect-pits, sunk upon the ore at various points. As many of these have caved in, so that the ore cannot be seen, and its quality can be judged only from what remains in the waste-dump, I shall describe only those at which the ore can be plainly seen and the thickness of the vein or its pitch can be determined with some degree of accuracy.

The Hayes Run opening is on the northwestern flank of Horse mountain, and shows a fine face of ore about 30 to 40 feet long and about 20 feet high, dipping northwardly at an angle of about 30 to 35 degrees. The whole face is rich, porous ore, with very little sandy material.

FIG. 6.

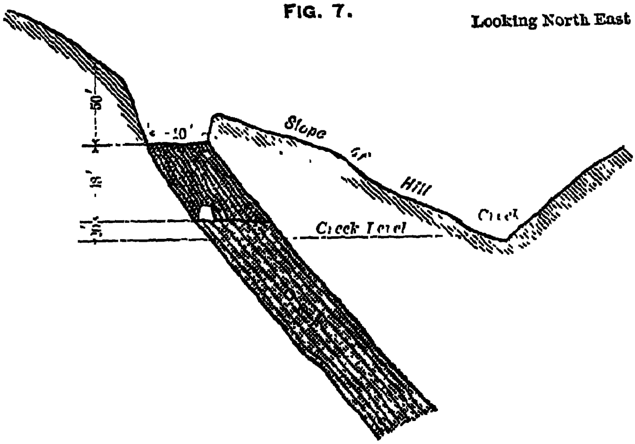
Looking North East



OPEN CUT OVER NO. 2.
Scale 1 in = 150 feet.

FIG. 7.

Looking North East



OPEN CUT OVER NO. 5.
Scale 1 in. = 150 feet.

The Smith, or Middle Ridge opening, is located about a mile and a half west of open cut No. 5. The cut is driven in a distance of 25 to 30 feet, with a face 10 or 12 feet high and 8 or

10 feet wide. It is entirely in ore and has not cut through the vein, so that the thickness of the latter cannot be determined. It appears to be certainly 20 feet thick, and may be twice that. The ore shown by this cut is a very fine mass of lump ore, open and porous, and with very little siliceous matter.

From this opening the trend of the ore-body can be followed to the top of the ridge by the large quantity of float-ore, which in places almost covers the surface.

Along the face of the divide, at the head of the branches of Clear creek, five or six openings have been made, showing that the outcrop follows around the head of the valley, just below the crest of the divide. None of these openings are more than mere prospect-holes, made merely to demonstrate the presence and continuity of the deposit. This object they accomplish, but none of them were sunk through the vein to determine its thickness, as other openings near by and the quantity of surface "float" ore were considered sufficient to determine this question.

On the head-waters of Laurel run near Clarkson's house, on the old turnpike, two small openings have been started under the ore-sandstone cap. They both show ore in place. The part of the vein exposed at both places is that lying next to the sandstone capping and is rather sandy.

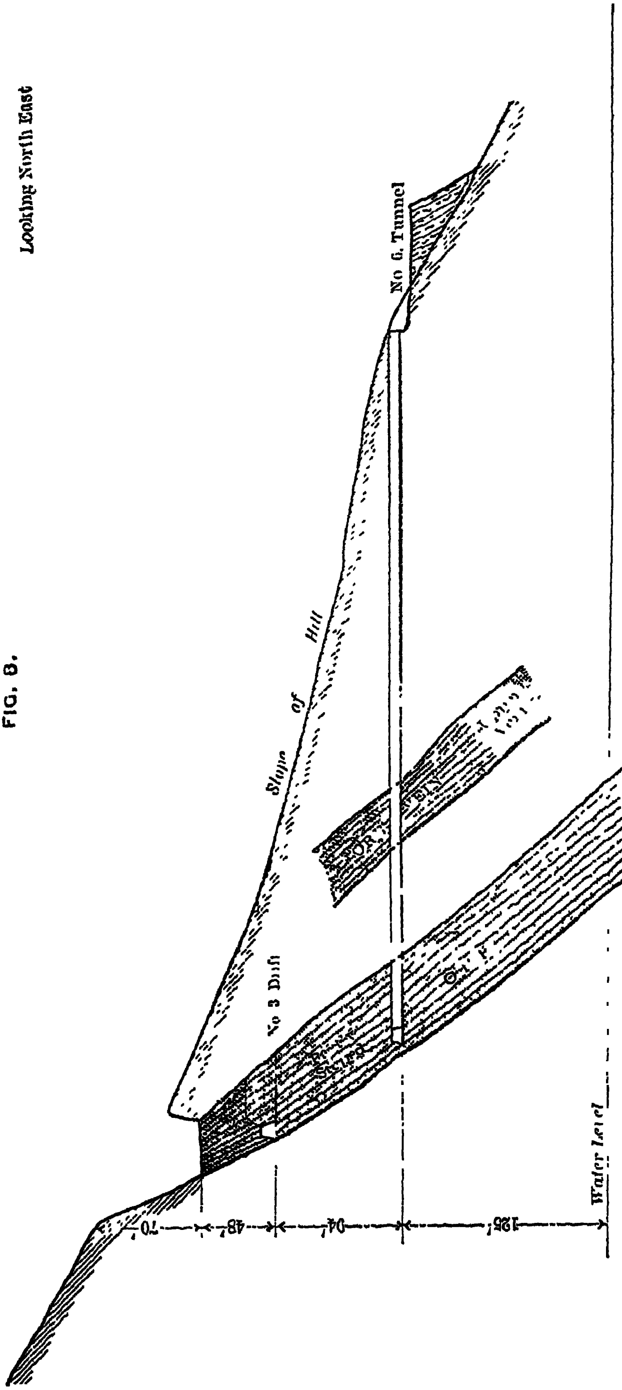
The Smallman opening is located about 1 mile west from open cut No. 5. It shows a very fine face of ore about 30 feet wide, with neither wall found. Ore has been mined from this cut and hauled by wagon 1 mile to the ore-washer, at a gross cost of $1 per ton.

Mining Methods.

Extraction.—The method used in extracting this ore is that commonly used in this region in mining brown-hematite ore under cover. The levels are driven close together, connected by up-raises which are used as chutes for loading the ore into cars on the main drift or car-level below, and each drift is robbed back from the boundary by withdrawing or blasting down the timbering, allowing the overlying material to fall behind, as fast as robbing progresses. By this method practically all of the ore is extracted, none being left in pillars, as is done in other styles of mining.

This method has reached its best development in this dis-

FIG. 8.



OPEN CUT OVER NO. 3. AND DRIFT FROM NO. 6. TUNNEL.
Scale 1 in = 150 feet

trict, on this property, and notably at the adjoining Low Moor property and at Longdale, where the same vein is mined.

Preparation of Ore for Market.—The method of preparation in vogue in this district is capable of material improvement without appreciably increasing the cost of the ore, and without involving a large additional outlay for plant. The ore is largely lump-ore, which requires no preparation. A variable percentage of the output is so-called "wash" ore, which consists of fine particles of ore ranging in size from wheat-grains to fragments 2 or 3 inches in diameter, and containing a little clay and sand, which are removed by washing in revolving cylindrical washers. The clayey matter dissolves easily in water, and the ore is washed quickly and effectively by the apparatus in use. It is evident that this apparatus does not remove particles of coarse sand, fragments of flint, sandstone and other impurities which may exist in the ore. Properly to prepare this ore for furnace-use, these impurities should be removed by jigging the ore, as is commonly done in many of our brown-hematite ore-districts. The addition of jigs would not only increase the percentage of iron in the ore as shipped, but would also materially decrease the percentage of silica.

The addition of jigs to the plant would also make it possible to utilize some lump-ore which is occasionally rejected because particles of flint or quartz are imbedded in the lumps. Lumps containing such quartz or flint are of occasional occurrence only, but in the aggregate they amount to a considerable quantity, which is, of course, rejected and thrown upon the waste dumps. This material should be crushed and jigged, and the washed product added to the washed ore.

The average of "wash-ore" shows about 60 to 80 per cent. of ore, or a loss in weight by washing of from 15 to 40 per cent., varying, of course, with the amount of clay and other impurities, such as sand, decomposed slate, etc., which the "wash-ore" contains.

The Discovery of New Gold-Districts.

BY H. M. CHANCE, PHILADELPHIA, PA.

(New York Meeting, February, 1899.)

THE recent discoveries of important new gold-districts in limestone, granite, sandstone and porphyry have awakened the more intelligent class of prospectors to a realization of the fact that any rock may be gold-bearing; that from the appearance of a rock it is impossible to judge whether it carries gold or not; and that gold-ores may occur in any geological formation.

As a rule, the professional prospector limits his search to ores and conditions with which he is more or less familiar, and to formations which he regards as favorable to the occurrence of such ores. Hence it often happens that while the very thing he is searching for is in plain sight, he fails to recognize it, and some other individual, possibly less intelligent but more lucky, stumbles blindly upon it.

Beginning with the discovery of the California placers by the finding of gold in the tail-race of Sutter's saw-mill—a tale so often told that nearly all have read it in some form—and following the discovery of district after district down to the present time, one is forcibly impressed by the fact that many of the important districts have been discovered by accident; that many such discoveries have been made by unskilled or inexperienced prospectors, and some by persons having no knowledge whatever of prospecting.

Thus, the recent Klondike discoveries are said to have been made by a poor salmon-fisherman, who, with his Indian wife, was hunting, not for gold, but for good fishing-grounds; the Comstock lode is said to have been accidentally discovered, and the Ragged Top district in the Black Hills and the Pearce mine in Arizona* are recent notable instances of the same kind.

* As the history of the Pearce mine is perhaps not so generally known as that of the two other cases mentioned, the following account may be of interest. This mine is situated south of Willcox, in Cochise county, Arizona. It is named after its discoverers, two cow-boys, sons of a miner, who employed themselves, when

Most of the gold-mining districts of the central Rocky mountain region were discovered by prospectors through more or less systematic search; but many important discoveries within these districts have been the result of accident, and have been made by outsiders, or by local prospectors, in most unexpected localities.

Thus, the original discovery of the gold-deposits in the Mercur district in Utah was a pleasant surprise to the finder. This district, then known as Camp Floyd, had been long prospected and worked for silver-ores. Assays of rock presumed possibly to carry silver, but not suspected to contain gold, showed the presence of the more precious metal in workable quantity. Similarly gold-mining in the Ragged Top district of the Black Hills was started by the finding of siliceous gold-ores in the limestone formation. After years of prospecting for silver-lead ores in the same region, boulders of siliceous gold-ore (averaging $100 per ton in car-load lots) lay on the surface in quantity. Miners by the score had traveled across the ground for twenty years, but it remained for a discouraged prospector, like a "drowning man catching at straws," to have a sample of these boulders assayed, and thus to discover that they were high-grade ore.

Similarly the Pearce deposit in Arizona showed on the surface boulders of ore that had doubtless been seen by hundreds of miners and prospectors, who regarded the material as worthless brecciated porphyry, which indeed it resembles; and not until a couple of cattlemen, prompted by curiosity, had a piece of this material assayed, was its value discovered.

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not "punching cows," in working on the vein with a windlass. In the course of a year they had sunk, I believe, about 50 feet, and drifted some 37 feet, without stoping. This work yielded them about $30,000 net profit—the ore, which resembled a brecciated porphyry, assaying from $60 to $70 per ton, one-third of the value being gold and two-thirds silver. They then gave to Philadelphia parties a "working-bond" on the mine at the ultimate price of $300,000, upon a preliminary cash payment of $18,000 and an agreement to spend at least $12,000 in development. At that time all the sides of shaft and drift were in ore—no vein-walls being visible. The intending purchasers expended about $1500 in equipment (hoist, etc.), and took out in three months enough ore to pay the price fixed for the property. The mine has continued for nearly two years to pay at about the same rate—$100,000 per month, net.

I do not think any western miner would have given any serious attention to this "ore." It is in appearance, according to all the accepted rules and traditions, most unpromising stuff.

It is almost impossible to visit any mining camp without learning of some important discoveries that may be termed accidental.

Men, women and children, engaged at all sorts of occupations and under almost every conceivable condition, have made important discoveries. A farmer, sinking a well or digging a post-hole; a woman, out berry-picking; a boy, hunting rabbits or foxes; a picnic-, fishing- or hunting-party; a lumberman cutting timber; a ranch-man seeking water; the upturned roots of a tree blown down; and many other such accidental circumstances and agencies have led to the discovery of mines.

While, in the aggregate, the discoveries so made are doubtless much smaller in number than those made by professional prospectors, they comprise many of the most important and valuable mines. This may be explained by the fact that unless a discovery so made makes a very promising showing at the surface, it is probably abandoned and soon forgotten, whereas discoveries made by miners are usually not abandoned until considerable work has proved them worthless.

Again, the "tender-foot" prospector, *i.e.*, one having no knowledge of ores or mining—searches at random, without method or system, and in localities passed over as unpromising by the more experienced prospector, who sees in them no indications of the presence of valuable deposits. To the former, all rocks are alike; and since, in searching for ore, the "tender-foot" does not confine his tests and assays to any particular kind of material, it sometimes happens that a stone of most unpromising appearance to a skilled eye may be found to carry mineral in valuable quantity.

Until quite recently the prospector's sole method of testing for gold was to crush a small quantity of the material in a mortar and pan the pulp to see if any free gold was present. If a "prospect" or "color" was found, the miner was encouraged to do further work on the deposit; but if, on the other hand, the material failed to "prospect" (*i.e.*, showed no visible free gold), it was abandoned as worthless; for without such a favorable preliminary showing few miners would incur the expense of having assays made.

All this is now changed. On every side prospectors express

the opinion that the only safe way is to assay everything, however unpromising in appearance; and, in some districts, prospecting now involves assaying as the principal part of the work to be done. Many prospectors, unable to pay for assay-work done at a regular assay-laboratory, have equipped themselves with more or less complete assay-outfits, and do their own work. In some cases they, in a wagon, on prospecting-tours, carry a portable assay-furnace, etc., and assay all sorts of rock—anything, in fact, differing in appearance from the general country-rock.

The results of such work are not only in many cases surprising and interesting, but are adding much to our knowledge of the distribution of gold.

During the course of examinations made in 1897 in the (Carboniferous) limestone plateau-country which encircles the central area of the Black Hills of South Dakota, I became personally familiar with much work of this character. Only in the northern portion of this plateau had mineral deposits of note been found; and it had been generally assumed that the mineralization of this formation was confined to that northern area.

I found, however, a general mineralization, extending in zones or belts throughout the region. Wherever there occur beds of siliceous material (which often assumes the form of true jasper, red, banded, yellow or nearly black in color), or wherever the sandy limestones or calcareous sandstones were more or less specially silicified, I found gold present in quantities ranging from $1 to $5 per ton, the true "arrow-head jasper" often showing values of from $2 to $3 per ton in gold. The quantity of gold seemed always to bear some relation to the physical structure of the stone, being largest where the stone was most altered by the infiltration of silica. As a rule, the unaltered limestones and sandstones gave nothing, or a mere trace of gold.

As a result of "assaying everything" for gold, the chemist of the Cambria Coal Company (which operates a bed of coal lying at the base of the Cretaceous formation, immediately west of the above-described limestone-plateau) informs me that he finds that their coal carries gold in values ranging from $1 to $5 per ton. While it takes about 2 tons of this coal to make

a ton of coke, the coke apparently carries no more gold than the coal. The owners of these mines claim that the coke carries an average of $2 gold per ton. While this amount would not justify a separate treatment for gold-extraction, it might conceivably be a decisive factor in the choice of a metallurgical fuel for smelting gold- or silver-ores.

That gold may be present in such quantity as to form very rich ores without showing any gold in a free (*i.e.*, a visible or directly amalgamable) state, is now generally known by prospectors, who know also that this form of occurrence is not limited to the silver-lead-gold, silver-gold, copper-silver-gold, and copper-gold ores, in which the gold is occluded in other minerals or exists in the form of alloys or other combinations or in pyritic minerals, but that the statement includes gold-ores [illegible] no other mineral or precious metal in appreciable quantity.

The most striking illustration of this form and manner of occurrence is found in the Cripple Creek district, where the gold-bearing minerals are sylvanite and other forms of tellurium combinations.

There seems to be, however, still another form of occurrence recognized, but not yet well understood, in which none of the tellurium minerals can be seen or separated. An example is furnished by the highly siliceous ores of the Ragged Top district, which contain neither precipitable free gold nor any heavy mineral carrying gold. No one has been able, thus far, to demonstrate the form in which gold exists in ores of this class. Similar ores have been found at a number of points in New Mexico and in Colorado, notably in the Gunnison district. They range in appearance from an amorphous horn-stone flint, with conchoidal fracture, through all the varieties of highly siliceous jasper-like minerals to chalcedony, sometimes having the grain and texture of a razor hone-stone, sometimes exhibiting a porous character, with small, irregular vugs, and varying in color from dark gray through all the shades of yellow and brown to red. Sometimes they are almost white or pearly, and again often of a waxy luster and color, the waxy varieties being dark in color, bordering on a dull wine-color.

Ore of this latter character from the Ragged Top district often assays from $100 to $200 and more per ton, but fails to

yield any concentrates carrying more than $10 per ton in gold, and shows not a trace of free gold. These ores show by analysis a very high proportion—about 95 per cent.—of silica, a little iron, alumina, lime and water making up the remaining 5 per cent.

Mr. Pearce, of Denver, and Prof. Smith, of Deadwood, formerly of the Rapid City, South Dakota, School of Mines, have called attention to the presence of tellurium in these ores; but the mere presence of tellurium cannot be held to demonstrate that the gold exists as a telluride, and this assumption is rendered improbable by the failure to find tellurium minerals, and by the failure of the most careful tests with very rich ore ($200 per ton) to get any heavy concentrates carrying more than about $10 per ton in gold. Again, tests of roasted and unroasted material have given practically identical results—which would be strange if the gold exists as a telluride. For these reasons it appears probable that we have here to deal with a class of deposits in which gold exists in some unknown condition in, or combined with, a siliceous matrix, and that this gold compound is not appreciably heavier, and possibly may be even lighter, than the gangue.

How widely ores of this character are distributed throughout the mineralized areas of the West is unknown, but the possibility of their existence should be recognized by every prospector.

There are few parts of the mineral lands of the West that have not been more or less prospected, and while discoveries of new mines or veins in old districts are continually being made, the discovery of new districts is an occasional occurrence only. That we do not know all the possible forms in which the precious metals exist may perhaps be regarded as fortunate, as tending to restrict the number of discoveries, and thus to allow time for the thorough development of one district before attention is distracted by new discoveries in others.

That new districts are not found more frequently is, doubtless, due to the fact, already sufficiently discussed, that the miner ordinarily restricts his search for ore to those formations and to that character of ore with which he is familiar, and may therefore for a lifetime walk daily over high-grade ore in plain sight, which in appearance so differs from his notions of

what constitutes an ore that he regards it as barren rock. This applies not only to the average prospector, but to the more intelligent class of engineers and assayers as well. I have been personally informed by the assayers, both men of wide experience, who made the first assays of ore from the Pearce mine, in Arizona, and from the Ragged Top district, in the Black Hills, that in both of these cases they tried to persuade the prospectors who brought in the samples not to waste their money on assays of what was apparently worthless rock. Among conscientious assayers this is a common practice. It has doubtless resulted in saving much to inexperienced prospectors, but it may often have prevented the discovery of valuable ore-deposits.

The Abrasive Efficiency of Corundum.

BY W. H. EMERSON, GEORGIA SCHOOL OF TECHNOLOGY, ATLANTA, GA.

(New York Meeting, February, 1899.)

I. The Relation Between the "Effective Hardness" of Corundum and its Content of Water.

In the summer of 1894, a specimen of corundum from Acworth, Ga., which was reputed to be of markedly inferior quality for the manufacture of corundum-wheels, was received by the Geological Survey of Georgia, with the request that it be analyzed, in order to ascertain whether this inferiority was associated with any peculiarity of composition. In its appearance there was nothing uncommon, though it seemed to be rather easily scratched with a knife, while, at the same time, it scratched agate easily. An analysis gave the following results:

Alumina, 94.58; silica, 1.77; magnetic oxide of iron, 0.69; calcium oxide, 0.44; and water, 2.51 per cent.

There is nothing unusual in this composition, except the amount of water, which is usually, in southern corundum at least, from 0.3 to about 1 per cent.

Concerning this corundum, the *Mineral Resources of the United States*, 1893, pp. 676 and 677, says: "It is supposed that this variety of corundum contains a little water, as it is

somewhat less hard and more easily cleavable than the common variety known as sand-corundum."

A similar opinion, that the presence of water indicates softness, is expressed in a private communication by Dr. T. M. Chatard, who says: "If the corundum gives more than 1 per cent. of water on heating to redness, I should think its abrasive quality doubtful."

Also, Dr. J. Lawrence Smith, in connection with the table of his results, given below, says: "And it would appear that, other things equal, those containing the least water are the hardest."

In view of the prevalent opinion that water indicates softness, and at the suggestion of Dr. David T. Day, of the U. S. Geological Survey, this investigation was undertaken, to ascertain if any relation could be traced between the amount of water and the abrasive efficiency of corundums.

At the present time, the only recognized method of determining abrasive efficiency is that of Dr. J. Lawrence Smith, described in the *Am. Jour. of Science and Arts*, November, 1850. It consists in grinding a weighed amount of the mineral to an impalpable powder, on a weighed glass plate, with an agate surface. The loss of weight of the glass is considered a measure of the efficiency of the corundum, or, as termed by Dr. Smith, the "effective hardness." In the same journal, January, 1851, he gives complete analyses of several corundums the effective hardness of which he had also determined. These analyses are as follows:

Analyses of Corundums.

Localities.	Effective Hardness (Sapphire, 100).	Specific Gravity.	Water. Per Cent.	Alumina. Per Cent.	Magnetic Ox. Iron. Per Cent.	Lime. Per Cent.	Silica. Per Cent.	Manganese. Per Cent.
Sapphire of India	100	4.06	......	97.51	1.89	......	0.80	......
Ruby of India.. . .	90	......	......	97.32	1.09	......	1.21	......
Corundum of, Asia Minor..	77	3.88	1.60	92.39	1.67	1.12	2.05	Trace.
Nicaria	65	3.92	0.68	87.52	7.50	0.82	2.01	......
Asia	60	3.60	1.66	86.62	8.21	0.70	3.85	......
India	58	3.89	2.86	93.12	0.91	1.02	0.96	......
Asia...........	57	3.80	3.74	87.32	3.12	1.00	2.61	......
India..........	55	3.91	3.10	84.56	7.06	1.20	4.00	0.25

The method of determining the water was to weigh the corundum into a platinum crucible, completely surround the

latter with quartz powder in an earthen crucible, and heat it in a furnace to bright redness for from half an hour to an hour. This method does not preclude the possibility of reducing-gases gaining access to the mineral, and thus, to a greater or less extent, reducing the peroxide of iron, a reaction which may perhaps account for discrepancies in the results.

It appeared advisable, therefore, to make the determination of water directly, by driving it off in a combustion-furnace, and catching it in a weighed calcium-chloride tube. The corundums for the test were kindly furnished by Mr. Francis P. King, then Assistant Geologist of the Georgia Survey. They were carefully freed from decomposition-products and gangue, then pulverized, as described in Dr. Smith's paper, in a diamond mortar, by striking a few heavy blows, then shaking out the powder through an 80-mesh sieve and repeating until enough had passed through the sieve for the purposes of the test. The powder was freed from iron by very dilute nitric acid, washed, dried at 100° C., and placed in weighing-bottles.

In determining the water, a gas-combustion furnace was used, with a porcelain tube glazed inside and out. A weighed amount of the mineral was heated in a platinum boat for one hour, with a slow current of dried air passing over it, under the pressure of a constant head of water. At the expiration of this time the boat was transferred to a desiccator, and the calcium-chloride tube to the balance, and, when cool, was weighed. As soon as the boat had been weighed, the corundum was transferred to a platinum crucible and heated for five minutes with the blast-lamp, care being taken to avoid any reduction of peroxide of iron. There was always a slight loss of weight on heating with the blast-lamp, which indicated that the temperature of the combustion-furnace was not sufficient to remove the water completely. That this was the case, was evidenced by heating some corundum for one hour in a porcelain crucible with a Bunsen burner, then determining the loss of weight, and then heating with the blast-lamp (when a further slight loss was observed), and, finally, in a platinum crucible, without further loss of weight.

The tests extended through three days, and on each day a blank charge was run, to ascertain whether the air was completely freed from moisture. There was always a slight gain in weight of the calcium chloride amounting to 0.0015, 0.0012

and 0.0016 grammes on the first, second and third days respectively. The average of these, 0.0014 grammes, was subtracted from the gain in weight of the calcium-chloride tube in all cases. The following results were obtained:

Determinations of Water.

Locality.	Water Calculated from Calcium Chloride. Per Cent.	Water Calculated from Loss of Boat. Per Cent.	Difference. Per Cent.	Loss on Heating with Blast-Lamp. Per Cent.	Total Water. Per Cent.
1. Unknown	0.36	0.30	0.06	0.11	0.47
2. Tennessee	0.27	0.27	0.00	0.09	0.36
3. Walton Co., Ga	0.80	0.75	0.05	0.04	0.84
4. Union Co., Ga	0.43	0.33	0.10	0.21	0.64
5. Track Rock mine	0.63	0.56	0.07	0.09	0.72
6. Laurel Creek, Ga	0.70	0.62	0.08	0.07	0.77
7. Austell, Ga	0.70	0.67	0.03	0.22	0.92
8. Powder Springs, Ga	0.39	0.34	0.05	0.11	0.50
9. Towns Co., Ga	1.06	0.82	0.24	0.11	1.17
10. Transylvania Co., N. C	.36	0.26	0.10	0.04	0.40
11. Sapphire mine, N. C	.45	0.42	0.03	0 08	0.53
12. Acworth, Ga	2.68	2.58	0.10	0.21	2.89

The water driven off by the blast-lamp in Nos. 1 and 9 was not determined; the average of the other determinations was taken for these. The last column is the sum of the gain in weight of the calcium-chloride tube, and the loss on heating with the blast-lamp.

It will be noticed that the gain in weight of the calcium chloride exceeds the loss in weight of the boat in every case, except No. 2, in which they are the same. The average difference is 0.07; and in only one case does it exceed 0.1 per cent.

In making the tests for effective hardness, it was found impracticable to pulverize the mineral until it ceased to abrade the glass; and the following procedure was adopted, after some preliminary tests, which showed that any further pulverization would not change the relative values appreciably:

Of the original sample, 0.7 gramme was weighed and divided roughly into four equal parts; and each part was pulverized for twenty minutes on a weighed glass plate, with the bottom of a small agate mortar which had been fitted with a handle. The plate was then washed and weighed, and its loss in weight, divided by the weight of the corundum, was taken as the effective hardness.

A separate plate was used for each corundum, though all the plates were cut from the same sheet. This was believed to be better than to use the same plate for all, as the increasing concavity of the glass, together with its possible variation in hardness at different depths, would probably cause as much error as could arise from variations in different pieces.

Repetitions of the test with the same corundum indicated that the resultant values were occasionally liable to vary as much as 10 per cent.

The results obtained, arranged in the order of their efficiency and compared with the percentage of water, are as follows:

Number.	6.	1.	10.	11.	5.	2.	9.	4.	8.	3.	7	12.
Effective hardn'ss,	0 409	0 340	0.326	0 311	0.274	0.274	0 255	0.247	0 247	0.242	0 210	0.207
Water, per cent,	0.77	0.47	0.40	0 53	0 72	0.36	1.17	0.64	0.50	0.84	0 92	2.89

From the above table it will be seen that No. 8, among the lowest in effective hardness, is among the lowest in water, and that No. 6, much the highest in effective hardness, is among the highest in water. Nor is there, in the other cases, much indication that low effective hardness is closely connected with a high percentage of water, or *vice versa*. At the same time it will be observed that, of the four samples highest in water, three occupy the lowest places in effective hardness, and that, of the four lowest in water, three occupy the highest places (save one) in efficiency.

The conclusion to be drawn from the above results appears to be that, while there is some relation between the amount of water and the effective hardness, it is not intimate enough to permit the estimation of one from the other, though it would appear, from Dr. Smith's results and those given above, that where water is very high, say over 2 per cent., the effective hardness is likely to be very low.

It was thought worth while to test the effective hardness of the corundums after they had been deprived of their water, to ascertain whether heating had affected this property.

The following are the values thus determined, before and after heating:

Number.	6.	1.	10.	11.	5.	2.	9.	4.	8.	3.	7.	12.
Before heating, . . .	.409	.340	.326	.311	.274	.274	.255	.247	.247	.242	.210	.207
After heating, . . .	.416	.355	.336	.304	.289	.289	.270	.244	.254	.291	.225	.270

It will be noticed that the values after heating are higher in all cases, excepting Nos. 11 and 4. The differences are nearly

all within the limits of possible error. But from the fact that they are nearly all in the same direction, it seems probable that heating to a high temperature slightly increases the effective hardness.

II. Smith's Test as a Means of Determining the Abrasive Efficiency of Corundum.

It has been already observed that Smith's test is the only recognized method of testing corundum for abrasive purposes. But while the method unquestionably gives the relative values of corundums used in the loose state, its accuracy where the corundum is fixed, as in a wheel, has been called in question. Mr. T. Dunkin Paret, President of the Tanite Company, in an elaborate article in the *Journal of the Franklin Institute*, Nos. 5 and 6, 1894, points out the differences between the conditions of Smith's test and those of the ordinary methods of using abrasives, and contends that Smith's test is valueless as a means of testing emery for such purposes. Dr. H. S. Lucas, the well-known manufacturer of corundum-wheels, in a private communication expresses a similar opinion as to corundum.

There seems to be good ground for doubt, at least, on this point, since in Smith's test the corundum is pulverized by crushing, while, if it be fixed, the force is applied in an entirely different way, and the relation between the resistances to stresses so differently applied may not be the same in different corundums. At the same time, no experimental evidence having been presented to support the objections thus urged, it seemed desirable to determine by experiment whether or not different corundums would give the same relative values with Smith's method and with a method in which the corundum was tested in a fixed form. The following is an outline of the method of testing adopted for this purpose:

A shallow brass box was fitted to the top of the rotating spindle of a centrifugal machine so that the bottom should be horizontal. A steel plate $\frac{1}{4}$ inch thick and 5 inches in diameter was placed in this and wedged tight. The test-piece of corundum, a small cylinder $\frac{5}{8}$ inch in diameter and about 0.8 inch long, made by cementing corundum-powder, was pressed upon the surface of the plate with a weight of 3.25 pounds, and the plate was rotated with a speed of 300 revolutions per minute. The test-piece was moved at intervals, so as to grind nearly the

whole surface of the plate. At the expiration of a certain time the plate and test-piece were weighed, and the loss of weight of the plate, divided by the loss of weight of the test-piece, was taken as the efficiency of the corundum.

The selection of a satisfactory cement proved to be a matter of considerable difficulty. As a criterion of the effectiveness of the cement, a piece of emery-wheel, supposed to have been a "vitrified" wheel, was ground down to the same size as the test-pieces, and compared with them. In most cases, it was found that the cement did not hold the particles of corundum firmly enough to permit their being torn to pieces, but rather that the grains were torn from the cement, without much comminution. Finally a cement was prepared, which, with the corundum used, gave an efficiency about twice that of the emery-wheel test-piece, and was consequently [illegible] in the experiments. The materials of this cement were water-glass and a strong solution of the mixed chlorides of calcium, magnesium and iron. The water-glass contained 10.2 per cent. of sodium oxide and 27.4 of silica, making a 37.6 per cent. solution of, approximately, $Na_2O, 3SiO_2$. The solution of the chlorides contained 40 grammes of ferric chloride, 35.5 of calcium-chloride, and 42.6 of magnesium chloride in 200 c.c. of the solution. This solution contains about equal weights of the three metals, and does not, in standing, appreciably evaporate or take up moisture from the air.

All the test-pieces were prepared, as nearly as possible, at the same time, as follows:

The corundum, selected nearly free from decomposition-products and gangue, was powdered in a steel mortar, then passed through a sieve of 80 meshes to the inch, and caught on one of 100 meshes. Of this powder, 10 grammes was weighed into a No. 16 paper shell, which served as a mould, the cap-hole being closed by a cork. To 3 c.c. of the chlorides 5 c.c. of the water-glass solution was added, and the mixture was ground in a mortar till thoroughly incorporated, and then poured into the shell on the corundum, and mixed with it by means of a wire. The corundum was then shaken down by tapping the bottom of the shell, and the excess of the cement was drawn off with a glass tube. A piece of bolting-cloth was then laid on the end of the shell, and forced down with a per-

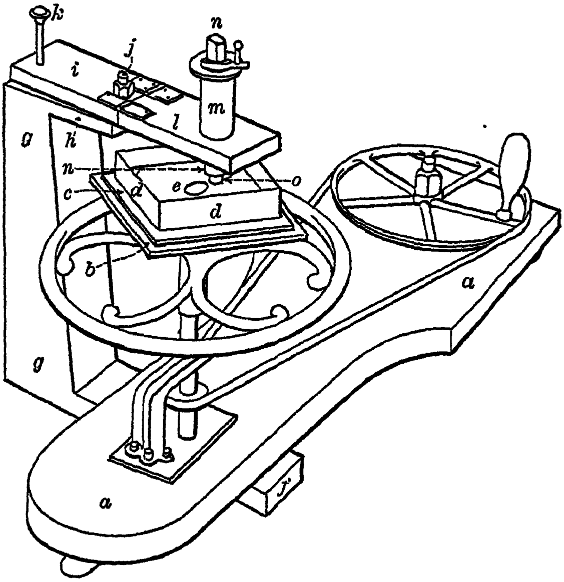
forated cork. The corundum was thus compacted by pressure on the cork, the bolting-cloth permitting the excess of cement to pass, but retaining the corundum. The shells were next put in a water-oven over night, then heated for one hour in an air-bath to 130° C., and then for half an hour at 230° to 240°. The moulds, which had partially charred, were trimmed off with a knife; care being necessary, as the pieces were fragile. They were next wrapped in platinum-foil to prevent sticking, and heated in a sand-crucible to the full heat of a brass-furnace for two or three hours. The test-pieces, at this point, were fairly coherent, but not sufficiently so; and after being ground down to the proper size for the holder, they were placed in a water-glass solution to which a little water had been added (1 c.c. of water to 12 c.c. of the solution), under the receiver of an air-pump (the air being exhausted); then exposed to atmospheric pressure for half an hour, and then put under the air-pump again. Finally, they were again heated in the brass-furnace as before, and were then strongly coherent.

It is, very likely, not necessary to use water-glass and chlorides of this particular strength; and it may not be necessary to use all three chlorides, or to apply them in this particular way. But in the preliminary experiments it was found that a test-piece made with water-glass alone was not satisfactory. Such a test-piece was then placed in calcium-chloride solution in an exhausted air-receiver, removed and heated, and was still unsatisfactory. A similar experiment was made with ferric chloride, with like result. This test-piece was next placed in water-glass solution and then heated, but without improvement. It was finally placed in a solution of the mixed chlorides of calcium and magnesium, heated and found to be very coherent, and for this reason the three chlorides were used. In the preliminary experiments, an excellent test-piece was made at a single heat by incorporating the water-glass and chloride solutions, mixing this compound with the corundum and heating; but for some reason the favorable conditions could not be hit upon again.

The apparatus used in testing is shown in Fig. 1. Rotation was imparted by means of a centrifugal machine, *a*, such as is used in physical laboratories, to which a brass plate, *b*, was secured by means of a stem perpendicular to its surface, so that

it would be horizontal and remain so while turning. Brass strips, *c*, were screwed to the upper surface of the plate, so as to receive and hold firmly a shallow brass box, *d*, about 1 inch deep and 5 inches square, which received the steel plate, *e*, to be ground by the test-piece. The steel plate was $\frac{1}{4}$ inch thick and 5 inches square, with corners cut off, and a hole in the center 1.5 inch in diameter. It was fitted close in the box and wedged tight. The holder for the test-piece was screwed to the machine by means of a heavy wooden piece, *f*, passing underneath. To this a strong upright, *g*, was firmly secured, from

FIG. 1.



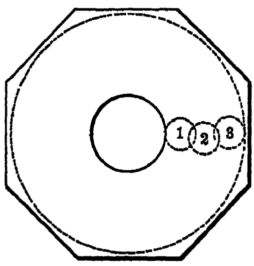
Apparatus for Testing Abrasive Efficiency.

the upper end of which a broad arm, *h*, projected out to, and slightly above, the box. Upon this arm, another, *i*, of the same size, was placed and held by a bolt, *j*, passing tightly up through both pieces, with a thread at the upper end to receive a nut, by which the two pieces might be clamped together, or loosened to permit rotation of the upper piece about the bolt as an axis. By means of a pin, *k*, passing through both of these, the upper piece could be fixed in any one of three positions. To the upper piece, a similar piece, *l*, projecting over the box, was secured by two strong strap-hinges. A brass cylinder, *m*, about 1.5 inch in diameter, passed through this piece with vertical axis, and

was secured to it by screws through a flange. A hole 0.75 inch in diameter was bored through the center of the cylinder and provided with a screw-thread of 102 revolutions to the inch, into which the holder proper screwed. This consisted of a cylinder, *n*, passing through the larger cylinder, and projecting an inch or so at either end. The upper end was squared to receive a small handle, by which to turn the screw. The handle could be fixed in any of four positions by means of a pin passing through a hole in it and into corresponding holes, 90° apart, on the upper end of the large cylinder. The lower end of the small cylinder was hollowed out to the depth of an inch to receive the test-piece, *o*, and was slit through on one side. The test-piece, with one or more turns of paper around it, fitted tightly into the holder, and could be further tightened by a nut on its outer surface.

The brass cylinders and the wooden piece to which they were screwed weighed together about 3.25 pounds. The material of the plate was a soft steel,* as it was found that with hardened steel, under the weight applied, the test-piece would become glazed and would almost cease to be abraded. A similar result was obtained with glass. On the other hand, a copper plate wore down the test-piece very rapidly; but steel was used, because it was thought that its action was somewhat more uniform under the given weight.

FIG. 2.



Scale ¼″=1 inch.

Diagram, Showing Successive Positions of Test-Piece.

It may be observed here, as possibly of significance, that the plate, as a whole, became, during the test, never hot, but only slightly warm to the hand—I should say, on a guess, 40° to 50° C.

In making the tests, pieces of round cardboard were first placed in the holder, so as to cause the selected test-piece to project about ⅛ inch, and the test-piece was then forced firmly down upon the cardboard and the nut was tightened. As a further pre-

* The manufacturers inform me that it was basic open-hearth steel, containing from 0.06 to 0.1 per cent. of carbon, and had been hot-rolled, annealed, pickled, and finally cold-rolled. I give this history of its manipulation since it may be pertinent to the question of variations of hardness in the plate.

caution, to prevent the test-piece from turning upon its axis, the inside of the holder was roughened by scratching it with a knife. The test-piece was then lowered upon the steel plate in the first or inner position (see Fig. 2) and adjusted perpendicular to the surface, and the plate was rotated at a speed of 300 revolutions per minute. At the expiration of a minute the test-piece was turned through one-fourth of a revolution, so as to dislodge pieces of steel which might tend to clog it, and, as was feared, to abrade the plate without corresponding abrasion of the test-piece. This was continued until a revolution had been completed, when the test-piece was slightly out of the vertical position, owing to the fact that the screw lowered it somewhat faster than it wore away. It was therefore turned backwards, so as to keep it nearly perpendicular to the surface. When the test-piece had been run for fifteen minutes in the first position it was moved to the second or middle position, where it was run for twenty minutes, and finally to the third or outer position, where it was run for twenty-five minutes. In this way the ground surface of the plate was kept nearly level. The steel plate was next washed, dried and weighed, and the test-piece was removed, brushed and weighed. The loss of the weight of the plate divided by the loss in weight of the test-piece gave the efficiency.

Duplicate test-pieces had been prepared from five corundums and one emery, and also a single test-piece from another corundum, of which there was hardly enough for one test, 7 grammes being used instead of 10. They were numbered as follows: 1 and 1*a*, location unknown; 2 and 2*a*, Acworth, Ga.; 3 and 3*a*, Iredell Co., N. C.; 4 and 4*a*, Macon Co., N. C.; 5 and 5*a*, near Sapphire mine, N. C.; 6 and 6*a*, Chester emery; 7,* Laurel Creek, Rabun Co., Ga.; 8, test-piece made from a piece of emery-wheel.

On testing these it was found that the same test-piece, while tending to a particular value, was liable to give, in successive tests, results varying too widely to make a single-hour test reliable. It was determined, therefore, to get an average value by extending the test over a period of six hours, which could be accomplished in one day. The plate was washed, weighed and

*No. 7, a gray corundum mixed with some blue, became a deep blue in the finished test piece.

reversed at the expiration of each hour. The stick was also weighed and moved down in the holder as it wore away, so as to allow a variation of not more than 0.01 inch in the amount of its projection from the holder. The plate was likewise raised as it wore down.

The pieces were tested in the following order, with the results given:

TABLE I.—*Six-Hour Tests.*

No.	Date of Test.	Steel Abraded. Grammes.	Corundum Abraded. Grammes.	Efficiency.
1............	September 9.	21.92	1.7716	12.4
3............	" 10.	20.58	1.4995	13.7
7............	" 12.	19.32	0.8803	22.0
3*a*...........	" 13.	20.83	1.3200	15.8
1*a*...........	" 14.	22.06	1.6368	13.5
5*a*...........	" 15.	21.20	1.3018	16.3
4............	" 16.	22.66	1.3806	16.4
2*a*...........	" 17.	20.83	0.9131	22.8
4*a*...........	" 19.	21.25	1.1722	18.1
2............	" 20.	22.04	0.9010	24.5
5............	" 21.	21.47	0.9360	22.9

On comparing the results of each pair, it will be seen that the later result is invariably higher. It was thought that perhaps some change was in progress, increasing the efficiency. On the following day, therefore, Nos. 1 and 1*a* were alternated. No. 1 gave an efficiency of 19.3 and No. 1*a* gave 18.4, which confirmed this opinion. The increase, it will be observed, is somewhat irregular, though it averaged about 5 per cent. a day.

As it could not be assumed that this change was constant, it now became necessary to alternate the test-pieces; and, as the plate was becoming thin, it was thought advisable not to use more than three. So 1 and 1*a*, 2 and 2*a*, 3 and 3*a* were chosen. These were alternated over a period of two days, which gave only two hours to each test-piece. The results are shown in Table II.

The plate had now become somewhat less than $\frac{1}{32}$-inch thick, and buckled so as to be unreliable. It had been about $\frac{1}{6}$ of an inch thick when the tests in Table I. began, and had worn away about 0.01 inch per day.

As the plate became quite thin, the change in the efficiency

TABLE II.—*Two-Hour Tests.*

No.	Steel Abraded. Grammes.	Corundum Abraded. Grammes.	Efficiency.	Average.
1...........	7.21	0.2867	25.2	24.7
1*a*..........	7.41	0.3062	24.2	
2...........	6.82	0.1730	39.4	36.1
2*a*..........	7.62	0.2313	32.9	
3...........	6.86	0.1807	37.9	38.2
3*a*..........	7.04	0.1822	38.6	
8*..........	3.88	0.2126	18.2	18.2

became more rapid. The test-pieces altogether in Table II. gave:

	Steel Abraded. Grammes.	Corundum Abraded. Grammes.	Efficiency.
First day, ...	21.58	0.7497	28.8
Second day, ...	21.38	0.6104	35.0

It had been observed that the exterior of the test-pieces was much more efficient than the portions just inside, though it was believed that this variation did not continue to the center, because the hard exterior abraded much less steel per hour than the softer inside, and if this variation continued, the amount of steel abraded per hour in Table II. should be greater than that abraded in Table I. by the same corundums, while in fact the difference is insignificant. As, however, this point was somewhat uncertain, the test-pieces were always ground down about the same amount before comparing them. The change in the efficiency noted above could hardly have been due to any change in the test-pieces, as the manner of testing would indicate. This was proved by alternating Nos. 1 and 1*a*, for half an hour each, on another plate, B, which had been worn down to the same thickness as that of the first plate, A, when the tests recorded in Table I. were begun. The results were:

	Steel Abraded. Grammes.	Corundum Abraded. Grammes.	Efficiency.
No. 1, ...	2.04	0.1770	11.5
No. 1*a*, ...	2.13	0.1901	11.2

The efficiency was less than half the value, 24.6, found on

* No. 8 was tested for one hour.

the former plate, A, when nearly worn away, and near the value, 12.4, found on it at a corresponding thickness.

The tests which follow were made in a slightly different manner from those above, as it was impossible to extend the test through a whole day, owing to other duties. The time on each test was reduced to 31 minutes (8, 10 and 13 minutes on the 1st, 2d and 3d places respectively), in order to be able to alternate six test-pieces in a half-day. Moreover the tests were not made daily, sometimes two days intervening. Alternated in this way, Nos. 4 and 4*a*, 5 and 5*a*, and 7 gave on Plate B:

TABLE III.—*Shorter Tests.*

No.	Time. Hrs.	Time. Min.	Steel Abraded. Grammes.	Corundum Abraded. Grammes.	Efficiency.	Average.
4	2	4	8.18	0.7169	11.4	12.3
4*a*	2	4	7.69	0.5837	13.2	
5	2	4	7.64	0.4307	17.7	17.3
5*a*	2	4	7.73	0.4592	16.9	
7	1	33	5.10	0.2164	23.6	23.6

In order to compare these values with those previously found for Nos. 1, 2 and 3, Nos. 2*a* and 5*a* were alternated, Nos. 6 and 6*a* being also tested at the same time. The results obtained for Nos. 2*a* and 5*a* were as follows:

TABLE IV.—*Special Tests.*

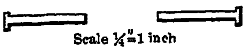
	Time. Hrs.	Time. Min.	Steel Abraded. Grammes.	Corundum Abraded. Grammes.	Efficiency.
No. 2*a*, . . .	4	4	16.56	1.0238	16.2
No. 5*a*, . . .	4	4	16.20	1.2140	13.4

With the emery, the results were altogether unsatisfactory. The cement seemed not to be suited to it, as large pieces were occasionally torn away, and the edges cracked off, while the corundum, on the other hand, was finely ground, and the edges of the test-pieces remained fairly sharp.

It was expected that No. 5*a* would show an efficiency somewhat higher than its previous value, conformably to the experience with Plate A, but on the contrary the new value was lower. That this was not due to any irregularity of the test-piece was indicated by the fact that the ratio between the values of Nos.

2*a* and 5*a*, found here, was about the same as had been previously found with Plate A, as the following comparison will show. The values of Nos. 2*a* and 5*a* in Table IV. have the ratio 1.21 to 1. Taking the values of Nos. 2*a* and 5*a* in Table I., and deducting 10 per cent. from the former for the estimated change in the two intervening days, we have the ratio 20.82 to 16.3, or 1.27 to 1. Also, taking the average of Nos. 5 and 5*a* in Table I., then the average of Nos. 2 and 2*a*, and deducting 2.5 per cent. from the latter, we have the ratio 23.063 to 19.6, or 1.18 to 1. As it is not probable that both test-pieces were irregular in the same way, we conclude that the variation was due to the plate.

FIG. 3.



Scale ¼"=1 inch

Cross-section of Steel Plate.

No. 8 was next tested for 31 minutes, and gave: steel abraded, 2.02 grammes; corundum abraded, 0.2626 gramme; efficiency, 7.7.

The irregularity noted above had not been expected, and could not be explained, as care had been taken to maintain the conditions as nearly uniform as possible. Of course, the wearing away of the test-pieces and the plate, thus exposing new portions, were unavoidable changes. Besides these, it is believed that there was only one other condition which was not maintained constant, namely, that which was due to the thinning of the plate, which would thus yield more and more to pressure (see Fig. 3).

Reasons have been given above for believing that the test-pieces were nearly uniform after getting through the exterior.

There appeared to be, then, but three sources from which the changes might arise: (1) thinning of the plate; (2) change in the plate from exterior to interior, possibly due to cooling after rolling or cold-rolling; (3) the actual physical effect of "cold work" upon the plate, modifying its properties. In the first case it would be necessary to assume that a plate, ¼- to ⅛-inch in thickness and 5 inches in diameter, would be appreciably deflected by a weight of 3.25 pounds; that this yielding would increase the efficiency of the test-piece; and that this effect was obscured in plate B by local irregularities, both plates having been cut from the same piece. The irregularity of plate B is brought out by the following table, giving the daily efficiencies in the tests made on it:

TABLE V.—*Irregularity of Plate B.*

No.	Time. Hrs.	Min.	Date.	Steel Abraded. Grammes.	Corundum Abraded. Grammes.	Efficiency.
4, 4*a*, 5, 5*a*.	2	4	Sept. 29.	7.68	.4890	15.7
" "	4	.8	" 30.	15.37	1.1349	13.5
" "	2	4	Oct. 1.	8.19	.5564	14.7
2*a* and 5*a*...	1	2	" 4.	3.83	.1840	20.8
" " ...	1	2	" 6.	4.44	.2104	21.1
" " ...	2	4	" 8.	8.52	.6754	12.6
" " ...	1	2	" 11.	4.19	.3408	12.3
" " ...	1	2	" 13.	4.05	.2776	14.6
" " ...	2	4	" 15.	7.73	.5496	14.2

During this time Nos. 6 and 6*a* were being alternated with 2*a* and 5*a*, and No. 7 with 4, 4*a*, 5, 5*a*, so that the abrasion of the plate was greater than the table shows. The weight at the beginning of the tests was about the same as that of Plate A on beginning the tests of Table I., and at the end of the test it was about the same as that of Plate A at the end of September 14th, having lost about 100 grammes. Greater irregularities might have been expected in this table than in Table I., as the duration of the tests was shorter.

On the second hypothesis, we would have to assume, as observed above, that the effect was obscured in Plate B by local irregularities.

On the third supposition, we have to assume that continued cold work gradually weakened the metal, and that in Plate B this effect was obscured by irregularities; or else that the periods of rest permitted the metal to recover, and even exceed, its original strength.

That a period of rest had the effect of increasing the efficiency is suggested by the fact that the two first tests of the day in Table I., on the rested surface, gave an efficiency about 6 per cent. lower than the average for the whole day. The average efficiency from the whole of Table I. was 18.0; the average for the first 2 hours was 17.1. On the assumption that 5 per cent. was the daily change, this difference should have been 1.6. This is more strikingly shown by a comparison of the weight of steel ground from the plate per hour, for the first 2 hours and for the day:

	Grammes.										
Hourly average for first 2 hours, .	3.61	3.28	3.14	3.40	3.50	3.40	3.64	3.43	3.51	3.48	3.46
Per day, ...	3.65	3.43	3.22	3.47	3.68	3.53	3.78	3.47	3 54	3.67	3.58

The rested surfaces, without exception, resisted abrasion better. Taken together, the first 2 hours average 3.44 grammes, while the average for the whole time is 3.55 grammes. The third and fourth hours averaged 3.58, the fifth and sixth 3.60 grammes.

If rest alone produced this effect, it would seem that "fatigue" should have increased the amount of steel abraded per hour. On comparing the amount of steel abraded by the duplicates in Table I., we see that, with one exception, the later result is slightly higher, and that the exception (No. 4*a*) followed a day of rest. Moreover, the amount of steel abraded in the second half of the table slightly exceeds that in the first half, even when No. 7, which is a little low, is omitted. The difference, however, is small. It has been noted above that the amount of steel abraded per hour in Table II. differed but little from that in Table I., for the same corundums. It should be said, however, that a half-day of rest intervened between Tables I. and II., and a full day of rest separated the two days of the test. The latter rest, being longer, may account for the smaller abrasion of steel on the second day.

In this connection, however, it should be pointed out that even when a day of rest had intervened, and the actual amount of steel abraded was smaller, the rise in efficiency still continued.

These details concerning the variation in efficiency have been presented thus fully in the hope that some one with a wider acquaintance with such facts may be able to give an explanation throwing light upon the matter.

Having obtained the relative efficiencies of Nos. 5*a* and 2*a* as above, we can now construct a table giving the relative values of all the corundums tested. No. 4, being the lowest, is taken as unity.

TABLE VI.—*Relative* [illegible] *of Samples.*

Nos.	4 and 4*a*.	1 and 1*a*.	5 and 5*a*.	2 and 2*a*.	3 and 3*a*.	7
Efficiency,	1.00	1.16	1.41	1.70	1.80	1.92

This table is constructed entirely from the values in Tables II., III. and IV. Comparing it with the values in Table I., on the assumption that the change in efficiency was 5 per cent. a

day, we get the same order, with the exception that Nos. 4 and 4*a* come above No. 1 by about 1.25, and Nos. 3 and 3*a* come very much lower. The values of the duplicates 3 and 3*a* agree fairly well in Table I., and still better in Table II. It appears, therefore, that the change in the plate had for some reason affected the efficiency of Nos. 3 and 3*a* much more than that of any other corundum. While the values given above cannot be claimed to be absolutely accurate, they give us at least the test-pieces very nearly, if not quite, in the proper order of their efficiencies at the time the tests were made.

The efficiencies of the corundums were next determined by Smith's test, as described above, except that the powder used for abrasion was some of that prepared for the test-pieces, and was therefore of a fineness between 80- and 100-mesh. Moreover, the corundum was heated and cooled twice, as had been done in making the test-pieces. The results obtained were as follows:

TABLE VII.—*Efficiencies by Smith's Test.*

No.	1.	2.	3.	4.	5.	7.
Efficiency,	0.334	0.272	0.277	0.309	0.328	0.468

Comparing this order of efficiency with that shown in Table VI., we have:

Order of efficiency, Smith's test,	No. 7—1	5	4	3	2
Order of efficiency by above method,	No. 7—3	2	5	1	4

There seems to be no relation between the two. Throughout the tests described above, No. 2 showed itself at all times to be among the best, while No. 1 showed itself at all times as one of the least efficient. Under Smith's test, on the other hand, No. 2 is lowest, while No. 1 is next to the highest, in efficiency.

It was thought that perhaps the corundum, through differences in composition, had not acted alike chemically on the cement, and that the differences in values from those determined by Smith's test might arise from variations in the tenacity with which the cement held the grains. Accordingly, a partial analysis of the corundums was made with the results shown in Table VIII.

In these analyses, the mineral was decomposed by fusion

TABLE VIII.—*Analyses of Samples.*

	1.	2.	4.	7.	3.	5.
Alumina	99.14	94.58	98.79	95.51	Und.	Und.
Magnetic oxide of iron	0.53	0.69	0.75	0.88	1.97	1.60
Silica	0.60	1.77	0.90	1.45	0.69	1.68
Loss on ignition	0.16	2.51	0.78	0.74	0.45	0.52
Calcium oxide	None.	0.44	Trace.	None.	Und.	Und.
	100.43	99.99	101.22	98.58		

with a mixture of equal parts of sodium and potassium carbonates. Perhaps it is not generally known to chemists how easily it can be decomposed in this way. From 0.5 to 0.75 gramme of the mineral was finely pulverized, mixed with from eight to ten times its weight of the mixed carbonates, and fused for about 20 minutes in a small platinum crucible, at the highest temperature obtainable with the blast-lamp. By the use of a strong blast and a flame about 2 inches in length, a portion of the lower edge of the crucible could be brought to nearly or quite a white heat. A small residue was invariably left, varying from 2 to 8 per cent. of the original mineral sample. This was readily and completely decomposed by a second fusion.

The efficiency appears not to be connected—at least not closely—with the composition. The analyses were not made with sufficient attention to details to ensure a high degree of accuracy, but the results obtained do not encourage the belief that more accurate analysis would reveal any important relations. We conclude, therefore, that the difference in values obtained by Smith's test and that described is not due to chemical action between the cement and corundum, and hence must arise from the different manner in which the abrasive force is applied in the two methods of testing. As a corollary, we draw the conclusion that Smith's test is valueless as a means of determining the efficiency of corundum, when applied in a fixed state, instead of a powder.

In the first part of this paper, attention was called to the fact that, in all corundums tested, the loss upon ignition was nearly equal to the amount of water; and we see from the tests of these corundums that the loss on ignition affords no evidence of close relationship between the amount of water and the efficiency by either method of testing.

Modern Gold-Mining in the Darien. Notes on the Re-Opening of the Espiritu Santo Mine at Cana.

BY ERNEST R. WOAKES, PANAMÁ.

(New York Meeting, February, 1899.)

CANA, originally called Santa Cruz de Cana, is situated in the province of Darien, in the Republic of Colombia, S. A. The river Cana is a tributary of the Tuyra, which flows into the Gulf of San Miguel, and thence into the Pacific Ocean some 80 miles S.E. of the City of Panamá.

The Espiritu Santo mine lies on the S. side of the Cana river at the foot of the Espiritu Santo range. The plateau of Cana has an elevation of 2000 feet above sea-level, and the mine is about 200 feet above the plateau. The map of the Darien accompanying this paper is the only correct one in existence. It was made by Lucien N. Bonaparte Wyse for the Panama Canal Co., and has been copied for the present use, with permission, by Mr. L. G. Inglis. The dotted line on this map shows the route from the coast to Cana.

As this mine was one of the most celebrated at the time of the Spanish occupation, it is only natural that there are a great many traditions and writings concerning its former workers and production. Dampier mentions it, though he does not seem to have been nearer to it than El Real de Santa Maria, the port on the Rio Tuyra, about 50 miles by road from Cana.

Señor Vicente Restrepo's work, entitled *Estudio sobre las Minas de Oro y Plata de Colombia*, translated by C. W. Fisher and published in New York in 1886, is, perhaps, the best treatise on Colombian mines. He has devoted a great deal of attention to the subject of the Espiritu Santo mine, and has had access to all that dealt with it in the archives of Bogotá. It will be interesting to quote a few passages from the above work, which seemed like a romance to the writer of this paper some years ago, when he first came across the history. Being actually in Cana at the time, and knowing the present company had

been working at a dead loss for three or four years, he had some reasons for suspecting that this earlier history was a fairy-tale. The sequel will show that this suspicion was, in great measure, the result of the refusal of modern "practical miners" to give due credit to ancient skill and industry.

The following are a few quotations from the above work:

"According to Dampier, the rich placers of Cana were first worked about 1665. He is the earliest writer who distinctly mentions the famous Espiritu Santo vein (the richest of all), and of which we are about to speak. . . . . In 1702 four English pirates, at the head of 272 men, captured the city of Santa Cruz de Cana and took possession of the mine, as the famous Espiritu Santo was then called." . . . .

"Nathaniel Davis, in his account of the 'Expedition to the Gold-Mine,' says: 'The mine is situated in the overhanging part of the hill; it is some 30 yards deep, and has many galleries that penetrate the hill farther than one would care to venture. The ore is a kind of *rock-mortar*. As soon as it is extracted it is taken to the mills to be crushed; then it is washed and made into bricks, and placed in buildings erected for that purpose, where there is a guard to see that the king is not defrauded of his share (the 20 per cent.). It is then washed again, after having been left in these buildings for some time, and in this washing the earth and minerals with which it is mixed are separated from the metals, leaving the pure gold.' . . . .

"We now come to the most important, the most complete and the most accurate of all the documents. Don Andres de Ariza, Governor of the Province of Darien, addressed to the Viceroy Guirior a long report upon this territory in 1774. He treats quite extensively of its rich gold-mines, and especially of the Espiritu Santo mine, referring to persons who have worked in it, and more particularly to its master and mover, Pedro Oramunio. 'The hill of Santa Cruz de Cana,' says Ariza, 'and others more to the north, are so abundant in ore that to speak of their magnificence seems more like hyperbolical exaggeration than actual reality. But as they are known not only by the stories of men of veracity, but also because there are at the present time various persons living who have actually worked in the famous Espiritu Santo mine, from whom exact information has been obtained, no doubt can remain of its vast wealth and positive existence in that place.' . . . .

"'The Espiritu Santo mine was in operation down to the year 1727. It was well equipped; the actual vein of gold it contained was very extensive and of such fine metal that it exceeded 22 carats. The direction of the vein was inclined or nearly perpendicular, so that it could be worked very profitably in spite of the great cost (*sic*). It had five ladders, of twelve or fifteen steps each, for the use of the operators in entering the mine. There were also four wells, in which the water that filtered through the earth was collected until it could be thrown into the river. . . . . More than 200 men were employed in it, who worked alternately night and day and in separate operations. They followed the main vein and several branches, which at times were found to be very rich, taking out of the mine earth and flat stones containing gold, which were sent to be washed. The miners were so placed that the ore, etc., was passed from hand to hand until the bottom of the shaft was reached, where, by means of a machine operated by two men in a wheel, it was drawn to the surface, where it was taken to the river to be

washed. . . . . The mine had four levels, but the lowest was the largest and widest. A great many miners worked in it without in the least interfering with each other. At intervals pillars of earth were left for support, and in some parts the excavations were lined with heavy timber, as protection against a cave-in. Unfortunately, this precaution was not taken in the shaft where the two miners worked the machine, and, the gravity of the soil overcoming its coherence, it caved in from all sides, burying, beyond the possibility of human aid, the two poor fellows who were employed in sending the soil up to the surface of the mine. . . . . This bad omen, together with the losses suffered through piracies of foreigners and Indian attacks, dismayed both owners and miners, who, fearing that the same accidents might occur in other parts of the mine, became panic-stricken (and are still believed to be so), ascended the ladders which were available, and resolved never to return to work. For this reason the owners of the mine gave it up and went to Panamá, nor did they return to this province.' . . . .

" 'Almost all the operatives of this mine were free blacks. Their wages, which they received every Saturday, were a small dish of earth for each day of the week; and if the owner thought the soil was poor in gold, instead of six of them, they would give them seven, which, after washing, would yield not less than 16 to 20 castellaños, and sometimes would yield 40 or 50. . . . . Nor were the wages of these unfortunate people their only source of riches; for they stole as well, and each time they went out of the mine (if, by chance, they were allowed to do so), and also when they carried their food in, they took the opportunity to go to the richest part of the vein, and from this, or from one of its branches, they stole the choicest ore. There was always abundance for both robbed and robber, the metal at that time being sold by the bottleful. Master Pedro Oramunio, who was in the mine at the time the shaft caved in, relates that whenever the workmen were in urgent need—as they knew well where the vein was located (though this was usually kept secret)—they would go to it, fill their pockets or a bag with the earth, and, when they thought the guards were asleep, would leave with their loaded bag, from which they would extract at least three to five pounds of gold. Such richness seems incredible, but numerous persons vouch for its truth.'

" 'As a confirmation of the magnificence of Santa Cruz de Cana, it is said that the negroes, mulattoes and *zambos* (children of Indians by negroes or *vice versa*) who worked in the mine, when they went to balls with their sweethearts would, to gain the favor of the ladies, sprinkle their heads and even their feet with the gold dust that they carried loose in their pockets. . . . . It is also an undisputed fact that a slave of Don Antonio de Sosa found in the mine a deposit, or, as the miners say, a pocket of gold, such as were frequently met with, but this being of unusual size, he went to his master with the news, asking for a reward. This his master granted him, setting him and his wife free, giving him a house in Panamá, a little farm, and some money besides to stock them with. Several persons assert that, according to the report of Señor Sosa himself, this pocket yielded 60,000 castellaños of gold (600 pounds); others say 50,000, but Oramunio declares that it gave from 16,000 to 20,000 castellaños (160 to 200 pounds), any one of which estimates indicates a magnificent yield.' "

The above quotations, chosen from many of a similar character, will be sufficient to show the past history of the mine. This ancient history brings us down to the year 1727, when, as is claimed, the workings were abandoned, owing to a serious

cave-in in one of the shafts, which happened simultaneously with an attack by the neighboring Indians. We next find that Mr. Bonaparte Wyse, in 1877, when surveying the Darien for the projected Panamá Canal, was taken to Cana by Don Francisco Rojas, and the mine was claimed on behalf of the Canal Company. The necessary legal forms were, however, not complied with, and the Canal Company lost its rights. Señor Rojas then interested some Bogotá people in the business, and a native syndicate was formed, which finally interested some French capitalists; but nothing of importance was done until Mr. Hammersley Heenan, of Manchester, England, was brought into contact with the French gentlemen. Being naturally of a sanguine disposition, and arguing that at any rate the ancient history was not written for the purpose of floating a modern company, he was immediately convinced of the genuineness of the old records, and an Anglo-French company was formed in 1888, with a capital of £200,000. The experience of the company for the next three years proved to be very similar to that of the majority of mining enterprises in new countries. The difficulties of starting work in an uninhabited tropical forest, 50 miles from the nearest port, were very great; but the most unfortunate part of all was that the management refused to believe in the old records, and started looking for new mines, which they thought it would be more profitable to work than to attempt to open up an old mine, which, if it ever existed, had in all probability been exhausted before the Spaniards left it. A vein-mine claim in Colombia is 1800 meters along the strike of the lode by 240 meters wide. The company owning some eighteen of these claims, there was plenty of room in which to locate a mine. Unfortunately, the choice fell upon the "El Rey" claim, situated nearly half a mile north of the Espiritu Santo, and on the other side of the Cana river. A fissure-vein on this claim was opened up by adit-levels, and some very rich rock was found in small quantities, together with a large mass of low-grade ore, the assay-value of which went very much higher than was ever after obtained in the mill. A 20-stamp mill was erected, and was run for nearly two years on the ore from this North mine, as it was called. By this time practically all the capital of the company had been expended, and as the ore was only running about $1.50 (gold) to the ton,

things had come to a very low pass indeed. Meanwhile the company had been reconstructed and the capital reduced to £100,000.

Matters were in this condition when the writer, who had been for some five years in the employ of the Tolima Mining Company, in the interior of the same country, found himself in the unenviable position of manager of an apparently played-out concern. After a few months spent in proving the lowest level of the North mine, which turned out ore of no better quality than the upper levels, the mill was shut down; most of the white employés were sent home, and all the remaining resources were turned upon the South or Espiritu Santo mine, where a small winze had been started by a previous manager.

At the time of the writer's first visit to this mine he was immediately struck with the appearance of the surface-workings. They resembled a long-deserted quarry, the bottom of which was filled up with broken rock and *débris*, with the water standing only 4 or 5 feet below the surface, so that it was impossible to sink a shaft without very considerable pumping-power. Surveys proved this bottom to be very much lower than any other part of the surrounding country—in fact, below the level of the Cana river. These open-cast workings are situated at the foot of a range of mountains, the large pit, more or less rectangular in shape, being about 120 feet long by 90 feet wide. From the N.W. corner extended a cutting, running at a very steep grade up the hill-side and terminating in a dry creek. In this cutting there existed two short prospecting-tunnels driven by the former management, on the results of which it is believed the mine was condemned. From the S.E. corner, the lowest part of the open-cast workings, a cutting in the solid rock, some 10 or 12 feet wide, with vertical sides over 30 feet high, extended in a straight line down to the lower reaches of the Cana river. This work in itself impressed the writer very strongly. The bottom of this cutting, which is called the Espiritu Santo creek, was also full of *débris* and rotten vegetation, and water stood in it within a few feet of the surface. The whole of the surface of the surrounding country and the old pit itself were covered with dense forest, and there was a small waterfall in the S.W. corner of the quarry. Explorations soon showed that on the almost vertical sides of these

workings there was a series of trenches cut in the rock, which, with a very little clearing and repairing, served to carry off the above-mentioned waterfall and other streams that formed during the heavy rains, and to divert them into the artificial cutting before mentioned, some distance below the mine.

From the above explanation it will be clear that this quarry or pit had evidently been excavated in the bed of a *quebrada* or creek, the waters of which were diverted; and that the deep cutting was used as a sort of open adit to reduce as far as possible the height to which the water had to be pumped. But it must be frankly admitted here that it was a long time after this that full justice was done to the capabilities of the old Spaniards as mining engineers.

The small steam-pumps from the North mine, together with the boilers and steam-hoist, were brought over and erected in a convenient position near the prospecting-winze before mentioned, which was situated in the country-rock on the N. side of the old pit. This winze was then sunk about 90 feet, when cross-cuts were driven to the S. and W. One fine morning the native miners came up with the news that they had "struck the river Cana in the S. cross-cut." Ten minutes later the shaft was filled with water to within a few feet of the surface, and the pumps were drowned. The only consolation seemed to be that it appeared pretty certain that we had found the mine we had been looking for.

The funds of the company were now fairly exhausted for a second time, but not the confidence of the chairman and some of the other directors. Surveys had shown that an adit-level, starting from near the junction of the Espiritu Santo creek and the Cana river, and carried at a very flat grade, could tap the old workings a few feet below the bottom of the prospecting-shaft, and that the distance in a straight line would not be more than 1100 feet. The writer undertook to carry out this work if £5000 could be raised. This was very soon done, and the adit-level was started August 11, 1893.

During the ensuing dry season a new sinking-pump was got into the prospecting-shaft, the workings were pumped out, and driving was started from this end to meet the adit. It was decided not to attempt any exploration of old workings until the adit-level had been completed.

On July 3, 1894, the two ends met, and the water, which had beaten the Spaniards and so disheartened all subsequent workers, flowed by gravity into the Cana river, leaving the long-lost wealth of the Espiritu Santo mine within our grasp. The actual length of this adit was 1080 feet, and it was constructed at a total cost of $18.20, Colombian currency, per foot. The labor employed was entirely native; and, besides the writer and his wife, there was present, during the whole of the operations, only one white man.

It was now an easy matter to drive cross-cuts through the lode, which was found to be riddled with old workings, but to contain considerable quantities of high grade ore, left standing to the S. of the deposit,—a conglomerate- or breccia-formation, some 80 feet wide from N. to S., and 120 feet long. The old stockholders, who had previously held back, were now anxious to get in, and sufficient capital was readily obtainable for a partial development and equipment of the mine.

A vertical engine-shaft was sunk to the 100-foot level (*i.e.*, 100 feet below the adit, or 250 feet from the surface). This shaft was connected with the old mill by a tram-road about half a mile long, and ten stamps were started on the *débris* from the old workings at the adit-level.

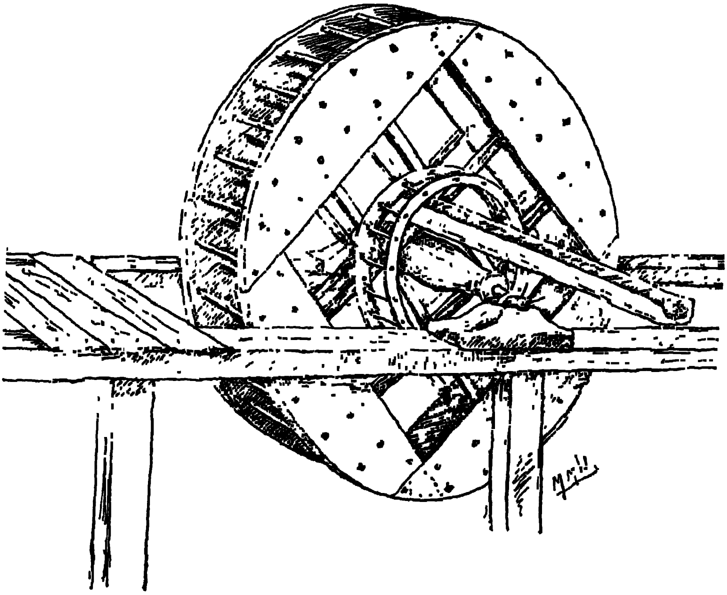
An air-compressor, operated by a Pelton wheel and a pipe-line and ditch from the Cana river, was soon erected to supply air for the pumps, and it was hoped that it would be only necessary to get the 100-foot cross-cut into the lode, when all the previous history would be verified. In these hopes we were again disappointed. The cross-cut cut the lode all right, but just as the rich rock was encountered we again went into old workings. This time they were more striking than ever, situated, as they were, 200 feet below the surface. Some of the workings were open and could be explored. Five tread-wheels were found here, some in a very perfect state of preservation; they were about 12 feet in diameter, and evidently raised the water by stages of about 30 feet each. They were all built on the same principle, and one of them is shown in Fig. 1.

The small drum, about 4 feet in diameter, is mounted on the spokes of the big wheel, and round it the endless chain of buckets was hoisted. The buckets dumped into a "dug-out" launder, inserted under the rim of this small wheel, through

which the water was conveyed to the sump of a similar wheel and again raised another stage. We now know that by this means the Spaniards raised about 80 gallons of water per minute to a height of nearly 200 feet. This gives one some idea of the hard labor their slaves had to endure.

Leather buckets, bateas, ladders and iron bars were also found. The ladders were made by cutting notches at regular intervals in an 8-inch pole; these were placed in pairs side by side, the steps breaking joint, so to speak, and, being placed at

FIG. 1.



Old Spanish Tread-Wheel, Found in Espiritu Santo Mine, Cana.

a convenient angle in the shaft, were easy to ascend. It appears that the ore was carried out in bateas, or possibly in hides.

The workings were found to consist chiefly of shafts, both vertical and inclined, and connected together without any apparent system, arches and pillars of high-grade ore being left between them. No doubt they followed to a great extent the soft, rich streaks which are found throughout the lode-mass. The timbering in these lower workings was found in some cases to be in perfect preservation; and it may be imagined that we considered ourselves fortunate in having seen such a marvellous piece of ancient mining 200 feet below the tropical for-

ests of South America, which had been buried and under water for nearly two centuries.

The old workings continued below our 100-foot level, though exactly how deep we do not yet know; our next level, which is 80 feet deeper, has not yet met any signs of them.

It appears that the upper workings had caved in entirely, and that the Spaniards had reopened the mine by a shaft in the country-rock to the East of the lode-mass. This would account for their lower levels being in so much better preservation than those we first met at our adit-level.

The system we adopted to extract the ore was by timbering with square sets. The presence of the old workings rendered the stoping very difficult at times, as the ground eventually got too heavy, and big runs were always occurring. However, since the mill was started up in 1895 the ore from above the 100-foot level has yielded nearly £65,000 worth of gold, and it is not yet exhausted. The next level is now opened up in the virgin lode, and it is only natural to suppose that it will yield splendid results.

A second engine-shaft, called the Maisounabe shaft, now in progress, will be carried down to the 340-foot level below the adit, or 500 feet from the surface. It is at present down 150 feet, and is being sunk at the rate of from 30 to 40 feet a month.

A very elaborate system of pumps has been put into the Heenan shaft. At the adit-level are placed two hydraulic motors, having a 6-foot 6-inch stroke, and connected by steel pipes to two distinct sources of water-supply; the higher, that from the Seteganti ditch, giving a working-pressure of 135 pounds. The power from these motors is transmitted by a pair of steel bell-cranks and hollow steel pump-rods to a double system of Rittinger hollow-plunger pumps, capable of pumping some 600 gallons per minute. All the castings of this plant are of gun-metal, and the foundations are cement-masonry or concrete. Previous to the installment of this pumping-plant the pumping was done with direct-action Cameron pumps, operated by compressed air.

The Ore-Deposit.—The ore-body at the Espiritu Santo mine presents several unusual characteristics, and deserves very careful study and a much fuller description than is at present possible.

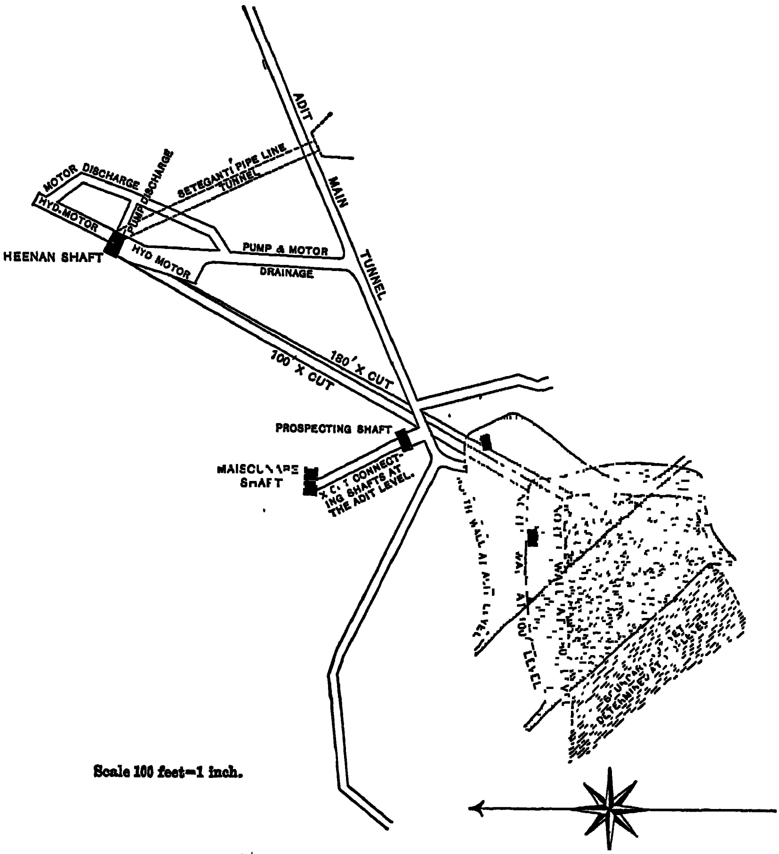
The country-rock is essentially andesite, in an extremely decomposed state. There are two predominating series of cleavage-planes apparent, the first, generally the most marked, running N. 55° W. with a westerly dip, and the second running N. 65° E. with a southerly dip. Roughly speaking, the ore-deposit appears to have been formed in an irregular quadrilateral, the boundaries of which are formed by these cleavage-planes, the N. 55° W. cleavages forming the east and west walls, while the N. 65° E. form the north and south walls. In adopting this theory liberal allowance must be made for the variations of bearing, such as would naturally occur in fissures running through such brittle and jointy rock. The sides of the quadrilateral figure are by no means equal or parallel in their entire length. The longer side or base of the figure may be taken as that forming the north wall of the deposit, the shortest is then the opposite or south wall. This gives to the figure the shape of an irregular truncated cone.

So far as can at present be seen, the extreme length of the deposit from east to west is 120 feet, while from north to south it is about 90 feet. Owing to the old workings in the upper levels it was not possible there to determine exactly the boundaries of the ore-deposit, neither are the present workings in the lower level in a sufficiently advanced state to permit of their exact determination. At the adit-level, or 100 feet below the surface of the open-cast workings, the north and south walls, or the N. 65° E. fissures, were very well defined; at the 100-foot level, or 200 feet from the surface, all four walls were very fairly defined, more especially so the east and west, or the N. 55° W. fissures. At the 180-foot level, nearly 300 feet from the surface, the north wall was fairly well defined, but not so the east and the south walls. The workings have not yet been carried up to the west wall. The east wall at this lower level appears to have been much broken up by other and nearly parallel fissures, situated to the east, outside the deposit.

The accompanying plan and section (Figs. 2 and 3) of the mine shows the more important of the underground workings, but it is here introduced more especially to give a general idea of the manner in which the ore-body has been opened up, the depth to which the Spaniards worked, and the general outline of the lode-mass so far as it is at present known.

It is, however, the formation and character of the ore-body itself which forms the most interesting study to the mineralogist, and is so striking in appearance to the miner. By far the greater part of the ore-body is composed of boulders and rock-fragments from the adjoining country-rock, varying in size from pieces as small as a walnut to masses of many tons'

FIG. 2.



Plan of Espiritu Santo Mine, Cana, Re-worked by the Darien Mining Co., Ltd.

weight. They are generally completely angular, but at times are as round as a pebble. In the writer's opinion this rounding is not due to the action of water, but rather to a process of decomposition. The rock-fragments are completely surrounded by concentric shells of brilliant crystalline sulphurets and calcite. The order of deposition of these minerals around the matrix is generally iron-pyrites, then blende, and then galena,

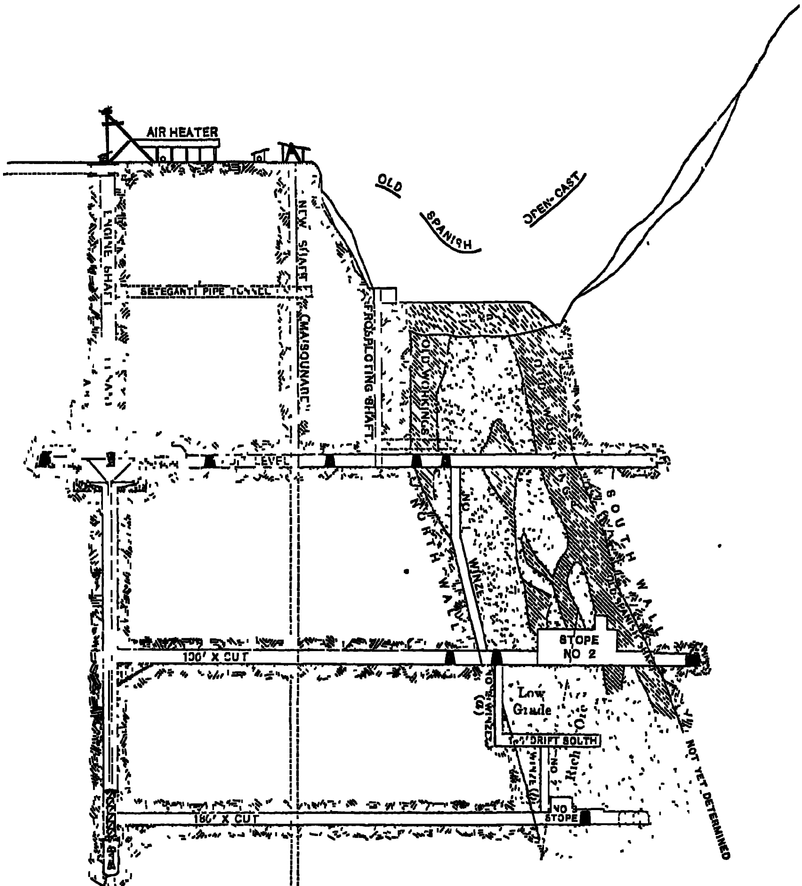
with an outer covering of calcite, in which occur acicular quartz crystals.

This structure is plainly shown in Fig. 4, the right-hand specimen being especially clear. The gold occurs for the most part in a crystalline form, but often as wire or strings. It is found adhering to the sulphurets, and no doubt the very fine gold is disseminated through them. It is a rule that the greater the percentage of zinc and lead sulphides in the ore, the richer it is in gold. Three distinct classes of ore have been observed in the lode-mass. In the vicinity of the walls, especially on the N. and W. sides of the deposit, the cementing-materials of the breccia are chiefly calcite and quartz, whilst the matrix is softer from more advanced decomposition. Here, therefore, we find low-grade rock. Immediately inside this mass, which varies from 15 to 40 feet wide at the different levels, and reckoning from N. towards the S., we find the interstices of the breccia not entirely filled up with cementing-material, an infinity of vugs being left. Here calcite, quartz and iron-pyrites, all more or less crystalline, form the cement. This class of ore assays from ·1 to 1.5 ounce of gold per ton, according to the amount of matrix present. The specimens on the left and at the top of Fig. 4 show ore of this class. To the center and S.W. of the lode-mass we find the ore very rich in sulphides of zinc, lead and iron, all more compact, the vugs being entirely absent. This may be said to be the best class of ore in the mine, and the specimen shown on the right in Fig. 4 is of this class. Occasional pockets and veins of a soft and friable mixture of all the lode-forming constituents are met, containing free gold in quantity. These the Spaniards seem to have followed with great assiduity, an example which we moderns are not above emulating.

With regard to the genesis of the deposit, the writer, while fully aware that he is on debatable ground in the discussion of such a subject, will hazard the opinion that the Espiritu Santo formation is indeed a case for the ascensionists. The cleavage-planes which abound in the district are generally filled with a few inches of clay, a little quartz and plenty of light-colored pyrites. They are invariably barren of gold. The North mine, before referred to, was situated on a N. 50° W. fissure, and contained no breccia formation, and hardly any zinc or lead sulphides.

The greater part of the lode-mass was a mineralization of the country-rock on all sides of several nearly parallel fissures, and the ore was of low grade. The writer has neither seen nor heard of a similar breccia-formation to the one above described anywhere in this country. There is a barren conglomerate in

Fig. 3.



Scale 100 feet=1 inch.

Section of the Espiritu Santo Mine, Cana, Re-worked by the Darien Mining Co., Ltd

a valley some 5 or 6 miles N.E. of Cana. Only in the immediate vicinity of the Espiritu Santo deposit have the fissures ever been known to show free gold, and then only within a few feet of the wall. It is true the fissures have never been followed to any extent to south and west, as it is the intention to do at

the deeper levels. The conclusion seems to be forced on us that an explosive eruption took place at a comparatively weak spot, primarily formed by a complicated intersection of a number of fracture-planes. The filling up and cementing together of the resultant rock-fragments would follow as a natural sequence, were the necessary ingredients at hand.

The Spaniards do not seem to have troubled themselves with the question of the genesis of their Espiritu Santo mine. They were evidently content to get out all the gold they could and leave the question of its origin to future scientists.

Stamp-Mill.—Fig. 5 shows the stamp-mill erected on the present site in the year 1890 to treat the ore from the North mine. It is, therefore, about half a mile from the engine-shaft at the South or Espiritu Santo mine. The site for this shaft was selected at such an altitude that a level tram-road could be constructed to run the ore to the mill. This road is laid with T-rails and is graded along the side of the hill. It crosses the Cana river on a trestle bridge 150 feet long, the widest span being 30 feet. The bridge is roofed with galvanized iron, to protect it as far as possible from the effects of the climate.

The mill contains twenty stamps in four batteries of five each. This entails the use of a pulley for each battery, which in many ways is an advantage, the short cam-shafts being less liable to fracture, and it not being necessary to hang up more than five stamps at a time. The ore is dumped into four grizzlies, the fines going direct into a bin which holds about 100 tons. The rock-breaker floor is immediately above the bin; the rock-breaker itself is a 10- by 7-inch Blake, constructed in sections. The ore is fed into the batteries by four Tulloch feeders, which are about to be replaced by the same number of Challenge feeders, which, it is believed, will be more satisfactory for the sticky ore treated. The mortars are of Frazer and Chalmers' sectional pattern. The stamps, with new shoes, weigh 850 pounds, and are run from 95 to 100 drops a minute, the height of drop varying from 6 to 7 inches. The shoes and dies are of chrome-steel, and, the ore being very soft, a set will sometimes last nearly six months. The mill is driven by a Pelton wheel under a head of 96 feet. A new ditch and pipe-line are now being constructed, which will give a head of 200 feet. All sorts of screens have been tried, and the most

satisfactory have been found to be 40-mesh clean-punched slot-screens of a variety made in England. They do not split, and they last from a month to six weeks. The height of discharge is varied by means of different-sized chuck-blocks; it is 8 inches when dies are new, and never more than 9.5 inches. The tailings from the mill are concentrated on four Frue vanners, which number will shortly be increased to six. The vanners are driven by a small independent Pelton motor, and another similar motor drives a dynamo at night, and a planer and moulder in the carpenter's shop by day.

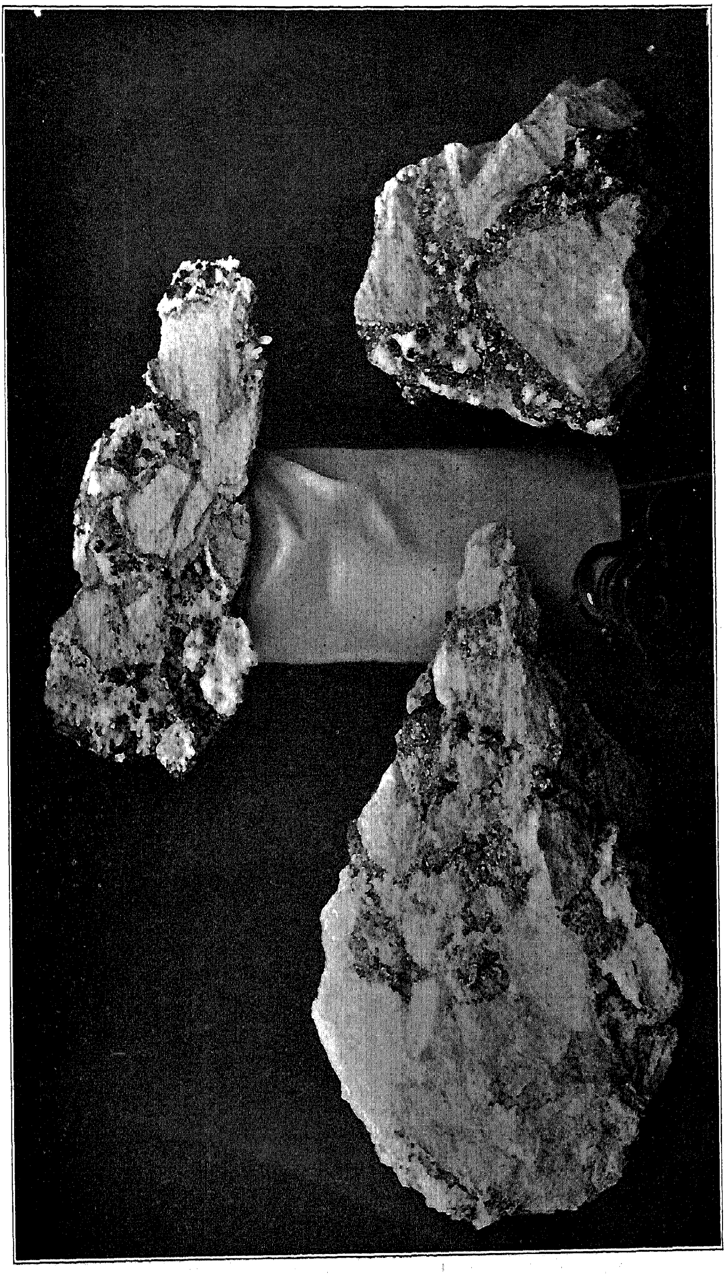
The mill was closed down for nearly three years after the abandoning of the North mine, during which time the timbers suffered terribly from dry rot and the ravages of the white ants, which latter are one of the worst plagues with which the mining engineer has to deal in these climates. Practically the whole of the mill-timbers, including battery-posts and mud-sills, have had to be renewed. Rather a novel method was tried in the renewal of the mortar-blocks, the idea being to simplify any future work of the same sort, in view of the fact that four or five years is the life of timber that is subjected to the sort of treatment the mill-timbers have to stand. The old mortar-blocks, which were 14 feet long, were taken out and the holding-down bolts of the mortars were lengthened to about 10 feet each. Portland cement concrete, constructed by running the waste-rock from the mine through the rock-breaker, was put in and rammed tight into the old foundations, reaching up to the level of the mud-sills of the battery-posts, forming solid blocks of concrete 14 feet long by 8 feet deep by 5 feet wide, under each double battery of ten stamps. Into these concrete foundations the eight hold-down bolts of each mortar were anchored, leaving their screwed ends standing out 4 feet 6 inches above the surface of the concrete; these bolts were of course placed so as to suit the holes in the bottom of the cast-iron mortars. Wooden blocks 4 feet high were now constructed of 3-inch planks, with their longer axis parallel to the line of the cam-shaft. These hard-wood planks were all planed and dressed by hand, and spiked and bolted together, holes being left by the proper spacing of the planks for the out-standing ends of the before-mentioned hold-down bolts to pass through. A sheet of rubber belting, taken from an old van-

ner-belt, was placed on top of the concrete surface; the short wooden mortar-blocks were lifted bodily up over the top of the bolts and dropped into their places; a similar rubber sheet was placed on top; and the mortar was finally put into its place; the hold-down bolts thus holding the concrete foundation, the short blocks and the mortar all together. The above process has been described at some length, as it is believed to be a departure from the orthodox plan. It is of course necessary to take very great care in the laying down of the concrete; in this case a mixture of three of rock, two of sand and one of best Portland cement was used, the proportion of cement being increased slightly towards the surface. Where the job was properly done the result has been most satisfactory, but in one battery a negro mason made a mess of his concrete, and the top portion had to be partly reconstructed after two and a half years' running.

When the ore from the Espiritu Santo mine was first milled very considerable trouble was experienced, owing to the hard and brittle amalgam that was formed on the plates; the work of cleaning up was very severe, and the plates got bad treatment from the amount of scraping that was required to remove the accumulated amalgam. As it is, each new mill-man who sees the plates at once condemns them, saying they are much too hard and that he will soon soften them up; but after his first month's run he has invariably altered his opinion, and admits that it is impossible to keep them soft as in other mills of his experience. Saturate the plates as you please, the mercury only runs off the lower ones, after an hour or so, into the traps. Inside plates were at first tried, but soon had to be given up, it being found that if enough mercury was fed into the batteries to keep the outside plates in a proper state the inside plates scoured and caught practically nothing. A large amount of partly amalgamated gold is caught with the battery sand, as can be seen by the table given below, and is collected with the stuff from the catch-alls in a clean-up barrel at the end of each month.

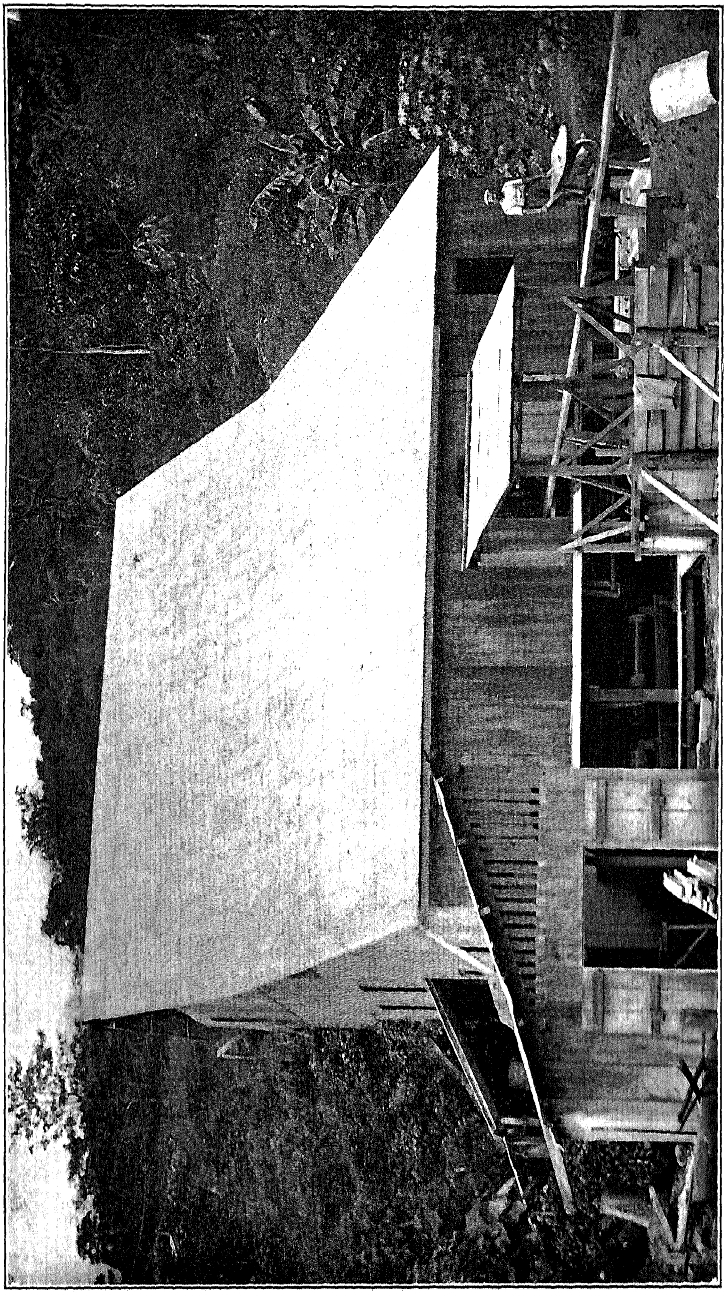
According to the method finally adopted, cast-steel liners are placed in the mortars in place of the back-coppers. Extending all along the outside lip of the mortar is a silvered copper plate 6 inches wide, which is held in place by the pressure of the chuck-block, under which it passes. A splash-board is placed

FIG. 4.



Specimens of Ore, Espiritu Santo Mine, Cana.

FIG. 5.



Stamp-Mill, Espiritu Santo Mine, Cana.

FIG. 6.

Heenan Engine-Shaft, Espiritu Santo Mine, Cana.

Fig. 7.

Cana, from the High-Level Mill-Ditch.

in front of the screens at such an angle as to lead the pulp well on to the top of this plate. Below this top lip-plate is a drop of 2 inches on to a second lip-plate 50 by 10 inches, also removable, to facilitate cleaning-up. Below this is an amalgam-trough 4 inches deep and 4 inches wide, and below this are the apron-plates 48 inches wide by 9 feet long. Below these are two more catch-alls or mercury-traps, from whence the pulp passes over the Frue vanners.

The ore yields from 3 to 5 per cent. or more of sulphurets, chiefly iron pyrites and blende. Every eight hours the plates are softened with mercury, well scoured and rubbed with rubber, to remove the loose amalgam; from this source is obtained the amalgam of the daily clean-ups in the table given below. At the end of the month the eight lip-plates are taken out and sandwiched in a box with hot sand, the latter being heated to near a dull-red heat and shoveled onto the plates. They are left thus for about half an hour, then taken out with tongs and scraped, the amalgam coming off like butter. The whole operation can be performed in an hour or so by two men; before the plates were so treated it would take half a day to properly scrape each plate. It will be noticed that the lip-plates yield a very large percentage of the total amalgam; it is also the heaviest and finest in quality. Hot sand is now spread over the upper 4 feet of the apron-plates; as it cools it is replaced by fresh, hot sand, until a trial shows the plates to be soft. Ten minutes' application of the scraper after the sand has been swept off takes off all the amalgam and leaves the plates in splendid condition for catching gold.

The following table will show the yield of amalgam for a typical month's run of ore from the 100-foot level, that is to say, the ore left behind by the Spaniards. The amalgam contains 36 per cent. of gold, and the melted gold is 932.71 fine:

Source.	Amalgam. Weight in oz. troy.	Per cent. of total.
Daily clean-ups,	606.5	24.00
Blanket-washing (by barrel),	23.7	0.94
Lip-plates,	815.7	32.28
Apron-plates,	461.8	18.28
Battery-sands and upper catch-alls,	590.3	23.36
Lower catch-alls,	28.6	1.13
Total,	2526.6	99.99

The hardness of the amalgam is attributed in the first place to the very high quality of the gold, which sometimes goes as high as 940 fine, and, secondly, to the extremely fine state of division in which a great portion of the gold occurs in the ore.

By the above method of treatment it might be supposed that a large loss of mercury would result; but such is not found to be the case. Care must be taken, in the case of the lip-plates, not to heat the sand too much; also not to return the sand from the box in which they are heated to the heating apparatus until it has been previously panned out, it being found that a certain amount of mercury sweats off the plates and gets condensed in the sand. Reheating before panning of course results in a loss of this mercury.

There being no smelting-works in the country, and the want of roads and high freights prohibiting the export of the sulphurets, it was necessary to find some means of treating them at Cana. Their assay-value varies from $30 to $100 or more per ton. Samples were sent to California for treatment by the chlorination process, which, for some unexplained reason, was found not to be at all satisfactory. Tests on a laboratory-scale by cyanide gave excellent results, and it was therefore decided to erect a trial cyanide plant.

Some fifty tons of concentrates were treated by the percolation-method, which gave an extraction of nearly 90 per cent. of the assay-value, with a reasonable consumption of cyanide; but it was found that the length of treatment had to extend over from fifteen to twenty days. It was therefore decided to try an agitation-process. For this purpose a barrel was constructed, capable of holding about half a ton of sulphurets with the proper amount of solution, and it was found that by running this at eight revolutions per minute for twenty-four hours practically the same percentage of extraction could be obtained as by percolation, and with a smaller consumption of cyanide. An agitation-plant, capable of treating 75 tons a month of the concentrates by the cyanide process, is about to be erected.

Mr. J. H. R. Robertson was in charge of these trials; and it may be incidentally mentioned that the value of the gold ob-

tained from them more than paid the whole of the expenses of the trial-plant.*

Communications and Roads.—The company has a small steamer which runs from Panamá to El Real, the port on the river Tuyra, two or three times a month, the journey taking about twenty hours. From Real to Cituro, the half-way station, is about twenty miles by trail cut through the forest. This road, however, is only used for passenger traffic and for bringing up cattle; all goods and machinery are taken up the Tuyra river by canoe as far as the mouth of the Cupé; thence that river is followed as far as it is navigable by these canoes, namely, to the Cituro station. This trip occupies from three to eight, or even more, days, according to the state of the river and the willingness or otherwise of the native "bogas." To the uninitiated the Cupé river would appear absolutely unnavigable, but by dint of hauling and wading, canoes carrying nearly a ton are got up to Cituro during the wet season. With a good river, the return trip may be made in twelve hours, and although, under such conditions, it is not unattended with risk, to undertake it is a most interesting experience.

At Cituro are some hundred acres of pasture-land for the use of the pack-mules and oxen. From Cituro to Cana is 19 miles, the Paca station being the half-way house. In summer the roads are dry and possible for wagons, but during the wet season they are little else but swamp. There are several considerable grades to be surmounted, which are at times almost impassable; in fact, the great drawback to mining in all these South American republics is the practical absence of roads.

* The latest mill-runs on ore from the 180-foot level (*i.e.*, from below the Spanish workings) have produced sulphurets of too low a grade to pay for cyaniding by the process above proposed. The ore from this lower level is very free-milling; and it now appears that the high value of the concentrates from the upper levels was due, in great measure, to the presence of fine rusty or tarnished gold which escaped amalgamation rather than to special richness of the sulphurets. This tarnish upon the free gold was probably caused by contact with water impregnated with decomposition-products from the timbers and other vegetable matter in the old workings.

The seeming exception thus furnished to the general rule that the ores of upper levels, being more highly oxidized, amalgamate more freely than those below, is highly interesting, but not perplexing It simply proves that the rule contemplates the release by oxidation of gold contained in sulphurets. If the sulphurets *per se* are poor in gold, and the gold is predominantly free, both above and below, the effect of surface-agencies may be to diminish the yield by direct amalgamation.

The company was fully alive to the necessity of improving the means of communication, and in the summer of 1897 engaged Mr. Eduardo Chibas (see his article, *Engineering Magazine*, October, 1898), who had considerable experience in railroad-making on the Isthmus, to survey the country between Cana and Cituro, and to report on the best means of improving the existing road. This gentleman advocated the construction of a graded macadamized road, and proceeded at once to lay it out. Work was then started on the sections that would avoid the worst portions of the old road, and at present about 8 miles of the new road have been graded and some 2½ macadamized. It is, of course, needless to add that the improvement is already very marked, and it is intended during the coming dry season to push on the work with all speed.

There is practically no agricultural industry in this part of the country, only bananas, plantains and a few root-vegetables being grown by the natives, so that all the food for the mining population has to be packed up on mules and bulls after reaching Cituro. An ordinary mule-load is about 130 pounds, and a pack-ox can bring up 200 pounds.

Seasons and Climate.—The seasons in Darien consist of a dry and a wet. The dry season commences at the end of December and lasts until the middle of April; during this time very little rain falls. The rest of the year is the rainy season, the wettest months being June and July, September and October. The rainfall for 1897 was 102.24 inches; for 1898 it was 94.78 inches.

The climate of Cana has been described by some enthusiasts as a sort of Eden; by others, again, it has been compared to a very different place. Perhaps if we strike a mean we shall not be far wrong. Situated as it is in the tropics, and at an elevation of a little over 2000 feet, it is certainly not unhealthy, though it is by no means every one who can live there and enjoy good health. There is certainly no *dangerous* fever, and Europeans or Americans who have anything of a decent constitution, and who do not abuse it, can well live there for from two to three years at a stretch without any detriment. There is reason to believe that the monotony of the life and the want of any diversion has as much to do with the bad name that Cana has acquired in some quarters as its much-abused climate.

Ditches.—There is a very complete system of ditches around Cana of an aggregate length of about 8 miles.

The Cana river supplies the stamp-mill and the old compressor by means of two ditches, each about 0.6 mile long. During the short dry season the water sometimes runs short from this source; hence a new ditch at a higher level is now under construction for the stamp-mill.

The Seteganti river is considerably larger than the Cana, and the ditch to bring its water to the mine is nearly 6 miles long. This supplies the high-pressure pipe-line for the hydraulic pump-motors and the new air-compressor, its overplus going on to the bulkhead of the old compressor, to augment the Cana water in the dry season.

These ditches all have the same grade, namely, from 12 to 16 feet to the mile. They were originally cut 4 feet wide on top, 3 feet on the bottom and 3 feet deep, but are now considerably larger by natural erosion. They are all cut on the mountain-side through virgin forest, the grading being 9 feet wide. The Seteganti ditch has a good deal of fluming and trestle-work, but it is found better to use as little of this as possible, even though a deal of extra grading and cutting be required to run around the numerous *quebradas*, the life of timber being so short in these countries. This ditch was constructed at a total cost of $24,000 Colombian currency, the whole of the work being done by natives on contract.

At Escucharuido, the river of that name is augmented by another, called the Limón, by opening an old Spanish ditch, some half a mile long, on a heavy grade. The two streams are taken by a canal, 6 feet deep, 7 feet wide and 300 feet long, to the saw-mill bulkhead.

As would be expected, the new ditches in this country require a good deal of attention during the heavy rains, the rainfall sometimes exceeding 3 inches in 24 hours. The lumber for flumes is cut on the spot with whip-saws, 1¼-inch plank and 6- by 4-inch scantling being used. This costs, placed on the banks, 9 cents, Colombian currency, per foot. The sub-soil in the district is mostly clay, the rock and boulders being andesite.

Brickyard.—A brickyard was started last dry season by a practical man from British Columbia. He has turned out about 150,000 first-rate bricks. In the dry season the work goes on

all right, but during the wet season it is very slow work drying the bricks. A limestone of fair quality has been found near the roadside, half-way between Cana and Cituro, and lime has been burnt.

Timber.—Every yard of the country may be said to be covered with forest. However, not 50 per cent. of the trees are fit for making lumber, and probably 25 per cent. are not even good enough for firewood.

It is necessary to fell all timber during the waning moon (*menguante*), otherwise it will commence to rot almost as soon as it is cut, probably owing to the rapid fermentation and decomposition of the sap which it is reasonable to suppose is present in the timber in larger quantities during the period of the waxing moon (*creciente*). The writer is well aware that many engineers will laugh at this idea and probably call it "moonshine." He can only trust that the scoffers will not neglect the precaution above described should they ever have to carry out works in these latitudes. The lumbermen from the Western States who first came here to get out the stuff for the erection of the stamp-mill of course laughed at the native ideas on the subject, with the result that the lumber which was sawn and piled up on the mill-site, awaiting erection, nearly all rotted before the retaining-walls were built and the carpenters were ready to start. This was a practical lesson by which they profited when they started to get out another lot.

Some of the hard-woods make beautiful lumber, and appear to be varieties of fustic, bullet-wood, nispero and wild guava, with occasionally a species of mahogany, of which the battery-posts in the mill are constructed. Hardly any of these woods will float in water. Cedar is now getting scarce, and is used for the finer classes of work only.

The old Spanish mine-timbers, which were found in such perfect preservation, were chiefly of *mapurri*, which is now scarce, and is never found of any great size. The segments of the Spanish wheels were made of *ispabé*, an enormous tree, a sort of bastard white cedar, which it much resembles in growth. It is plentiful and useful for rough boards. It was probably chosen by the Spaniards on account of its size and the ease with which it can be worked up.

Machinery and Plant.—Water being a free commodity, and

for the greater part of the year there being a superabundance of it, it has been the endeavor of the management to use it and compressed air for all power. With the installment of the hydraulic pumping-plant this will be accomplished. The compressed air, which was formerly used for pumping, will be available for the winding-engine, sinking-pumps and rock-drills.

The first power-plant consisted of a duplex 14- by 24-inch Schram compressor, driven by a Pelton water-wheel 15 feet in diameter, mounted directly on the axle of the compressor. The wheel is sectional (for mule-transport), and is constructed entirely of steel, with the exception of the buckets, which are of cast-iron. The strains are taken by eight tangent spokes of 1¼-inch round steel, so placed as to form a truss in the center-line of the wheel. The water is taken by a ditch from the Cana river, and is led to the wheel by a riveted steel pipe, tapering from 19 inches to 13 inches diameter and 1360 feet long, giving a vertical head of 200 feet. The air-receivers consist of two tubes, each 75 feet long and 20 inches diameter, of electric-welded pipes, 3 feet long each, riveted and lead-caulked. One receiver is situated near the compressor, and the other at the engine-shaft, distant 900 feet.

This plant is now being duplicated by a similar but improved machine situated close to the new shaft in the Espiritu Santo creek, and connected up to a similar pipe-line, supplied from the Seteganti ditch, under a head of 230 feet. This pipe-line also operates the hydraulic pump-motors placed at the adit-level, under a total head of 320 feet.

The motors are likewise connected with the pipe-line of the old compressor from Cana river; so that, in case of damage to either ditch, the other can be brought into play.

Adjoining the compressor-house is the machine-shop, containing a 10-inch and a 6-inch screw-cutting lathe, a boring-machine, zinc-shaving lathe for cyanide-plant, etc. These are all operated by a Pelton motor under 200-foot head. In connection with this motor is a dynamo for lighting the shops, mine boarding-house, pit-head and motor-stations underground.

Close to the shaft-mouth is a range of buildings used as smith's forge, mechanic's and mine-carpenter's and timbermen's shops. Here there is another small Pelton motor, work-

ing under 100-foot head, for blowers for forges and vertical drilling-machine.

Two small Hazelton water-tube boilers are used as auxiliaries for winding purposes. The fuel used is cord-wood, generally of poor quality, which costs about $4 currency per cord.

A reheating-furnace, by Frazer and Chalmers, is now in course of erection, to be used for heating the compressed air previous to use in the winding-engines.

The Heenan engine-shaft (Fig. 6.) is fitted with a double skip-road. Each skip carries 15 hundredweight of ore. The winding-engine has fast and loose drums, 4 feet diameter, with 12- by 6-inch steam-cylinders. The rate of hoisting is about 300 feet per minute. A small 6- by 12-inch single winch, with 2-foot drum and friction-clutch, is used for sinking the new engine-shaft.

The compressed-air pumps are Cameron and Knowles, 10- by 13- by 5-inch sinking- and station-pumps; also a Cameron station-pump 14 by 18 by 6 inches, for use in the new shaft later on, while the Heenan engine-shaft is deepened and the hydraulic pumps are lowered.

A planer and moulder and small saw-bench are run by a Pelton motor in the carpenter's shop, from connection with the mill pipe-line.

The manager's house is connected by telephone with the office. Fig. 7, a view of part of Cana, taken from the high-level mill-ditch, shows some of the Company buildings, the roofed tram-way bridge, and the general character of the country and the town.

The saw-mill is situated at Escucharuido, two miles from Cana, with which it is connected by a good macadamized wagon-road. The saw is a 52-inch "Hoe," with shifting teeth, run by a 30-inch Leffel turbine. This is a most effective plant, and supplies from 20,000 to 25,000 feet of lumber per month.

At Escucharuido are some hundred acres of fine pastures for the logging-bulls and wagon-mules. The pack-animals also use them during their stay in Cana, on the round trip to Cituro.

Labor and Economical Conditions.—There are two distinct sources of supply for the native labor employed on the mines—the imported blacks from the West Indies and the native Co-

lombians. The Darien not being a mining district, and being, moreover, very sparsely populated, the labor question would be troublesome without the West Indians. The natives know nothing of mining until they come to Cana. They are naturally indolent, but intelligent, and, for nearly all classes of work, are preferable to the West Indian negro. The inhabitants of Darien are, without doubt, naturally poorer specimens of their race than the inhabitants of the interior departments of the country. Their few villages being all situated on the rivers, they have no roads; and as the rivers abound in fish, they do not breed cattle or cultivate the land beyond growing a few plantains and rice for their actual wants. Their tidal river almost carries their dug-outs to Panamá and back again. Panamá, moreover, until lately being a free port, they have no necessity to manufacture anything; in fact, it may be truly said "They toil not, neither do they spin." The aboriginal Indians keep to themselves entirely, away up in their villages on the upper rivers; some of the tribes are even hostile to intruders.

The West Indians are lazy, obstinate, and very rarely appear interested in their work; they work like animals, because they are obliged to do so. There are, of course, a few exceptions.

The nearest source of supply for the mines is Panamá, which is five days' journey from Cana, with steamer-communication only twice a month. The Panama Canal works have proved a mixed blessing; when they were in active operation the wages were high; and, the supervision being very slipshod, the efficiency of the labor was very poor. The works served, however, to bring a number of West Indian families to the Isthmus, of which circumstance the mines now take advantage. In none of the mining districts of the interior of Colombia are West Indians found.

The following are the rates of pay for native labor of all sorts:

	Per Day.
Miners,	$1.80 to $2.00
Shovellers and wheelers,	1.60
Carpenters,	2.00 to 3.00
Mechanics and smith's assistants,	1.50 to 2.50
Laborers,	1.40 to 1.50

The company, of course, works under favorable conditions, producing gold whilst paying its labor in silver.

The cost of food and materials is rather high, owing to rates of exchange and cost of transport.

Dynamite,	per lb.,	$1.00
Candles,	"	.40
Flour,	"	.25
Rice,	"	.20
Lard,	"	.45
Salt,	"	.20
Sugar,	"	.40
Fresh beef,	"	.40

The native workmen's quarters were originally palm-thatched huts. These are now nearly all superseded by good-sized two-roomed cottages of sawn lumber, built up on hard-wood piles, roofed with galvanized iron and whitewashed inside and out. A monthly rent of $2 a room is charged. A large proportion of the men have their families in Cana. There is a large free camp for those who prefer it.

Men are encouraged to clear and plant the land with bananas, yams, etc., and annual licenses are granted them for this purpose. There are now about forty settlers who pay $4 a year per *cabuya* (a native measure approximately one hundred yards square).

All skilled labor is imported from Europe or America, and is paid at fairly high rates, in gold. The company boards and lodges its white staff.

The company has complete control of all trade and of liquor-sales. It runs a store in Cana where liquor is sold at retail; and, owing to this valuable concession from the Colombian authorities, very little drunkenness occurs.

So far, the Colombian authorities have done everything possible to assist the mining industry in the Darien; that is to say, their laws are all favorable, and no excessive taxes or royalties are imposed. With the assistance of its agent in Panamá, Don Luis Gaibrois, the company was enabled last year to acquire the actual freehold-rights of 5000 hectares, or 12,350 acres, of land in and around Cana. This more than includes all the surface of the mine-claims already held by them. It may be thus fairly said that the Company has its property in a "ring-fence."

It is, of course, easy to be wise after the event; but it is now evident that the error we have made all along has been in not

giving to the old Spaniards the credit they deserve as mining engineers. We took on the job after they had given it up, which no doubt they did not do until the obstacles met in working a deep wet mine could not be overcome without machinery that was not then available. The writer much doubts whether moderns would have done as much as the ancients did with similar appliances. No doubt the slave-labor was an immense advantage, economically.

Most people imagine they have first to find an old Spanish mine, then only to put up a mill and start a prosperous concern. This fallacy accounted in a great measure for the first modern workers becoming discouraged with the Espiritu Santo mine. They could not go there and find gold lying about for them to pick up. A thousand or so of men, working a mine at intervals extending over a period of two hundred years, are not likely to leave much gold lying about the surface. Had the present Darien company gone to work and sunk a shaft 500 feet, and properly equipped it, it would no doubt have reaped a golden harvest many years ago. Instead of that, the capital was spent in unprofitable work; and when, finally, the real mine was found, it was not thought that capital would be required to develop it—it would be so rich that it would at once make handsome returns. It is hardly surprising that it has not done so, although it has practically paid for its own development and installment of machinery, and now, no doubt, has reached a dividend-paying condition.

It must not be imagined that the writer is censuring the Darien company—far from it. It is hardly likely that there is another case on record of a limited company staying with a mine through good and evil report, and maintaining the price of its stock at a high figure, while patiently awaiting its well-earned reward.

The writer cannot close this account of his experiences at the Espiritu Santo mine without recording his admiration for the marvellous pertinacity and courage of the Spaniards. The carrying out of deep-mining operations, on the scale they did, in the heart of a hostile and tropical country, entirely cut off from all outside resources, is indeed an achievement. Viewed from a modern standpoint, their work seems almost incredible. Without machinery or explosives, and our regular mails and

remittances, what should we modern miners do? The wish for a glimpse of Cana two hundred years ago, with the workings in full swing, is a theme too tantalizing to be dwelt on. The ascendancy of the Anglo-Saxon over the Spaniard is surely due to other qualities than personal courage and power of endurance.

Note on the Disintegration of an Alloy of Nickel and Aluminum.

BY ERWIN S. SPERRY, BRIDGEPORT, CONN.

(New York Meeting, February, 1899.)

Some time ago, the author had occasion to make an alloy of equal parts of nickel and aluminum, for the purpose of adding small amounts of nickel to pure aluminum. The nickel was melted in a plumbago crucible under a layer of borax; and at a proper temperature the aluminum was added, and the whole mass was stirred with a plumbago stirrer. The alloy immediately became incandescent and boiled. It was then poured into iron moulds, in the form of ingots weighing about 10 pounds. The metal when poured was very fluid and free from the viscosity so often noticed in nickel and nickel-alloys. The color of the alloy is gray, not unlike that of wrought-iron, and the fracture is devoid of any crystalline appearance. It is quite brittle, and can be readily ground to a powder in a mortar.

More metal was made than was needed; and what remained unused was placed in a covered wooden box and set away. In about three months, as it was again necessary to use the alloy, the box was opened; and, much to my surprise, nothing but a dark gray powder was found in it. This condition of the alloy could not be accounted for. An attempt was made to melt the powder and pour it again into ingots, but with negative results. Analogy pointed to disintegration; and it was decided to make a fresh sample of the alloy, and watch the material from the beginning. In the second experiment the conditions were identical with those of the first, with the exception that fluor spar was substituted for the borax. This change was made because it was thought that perhaps the borax might have been

decomposed so that boron or sodium, or both, had entered the alloy. No difference could be detected between the appearance of this metal and that of the preceding experiment. The ingots, visible at all times, were allowed to lie in the open air. In about one month cracks appeared on the surface of the ingot, and, as time elapsed, became more extended and penetrated to a much greater depth; soon new cracks appeared and the ingot split into many large pieces. Such a change went on for two months more, or until the whole mass became a coarse powder.

The experiment was tried again by melting the nickel and aluminum together under a flux; and again, in order to make sure that no outside reagent was present in the alloy, the ingredients were melted without any fluxes. In each case the results were the same.

It is well known that many alloys are subject to disintegration, notably an alloy of tin and aluminum. Indeed, brass is subject, more or less, to this phenomenon; but the author believes that the disintegration of an alloy of nickel and aluminum has never before been observed.

An alloy of nickel 90 per cent. and aluminum 10 per cent. was made by the author September 16, 1895; and a recent examination of the ingot failed to reveal any trace of disintegration. Such alteration is limited, so far as yet observed, to the half-and-half alloy.

A Prospectors' Density-Rule.

BY J. HOLMS POLLOK, B.Sc., ROYAL COLLEGE OF SCIENCE, DUBLIN, IRELAND.

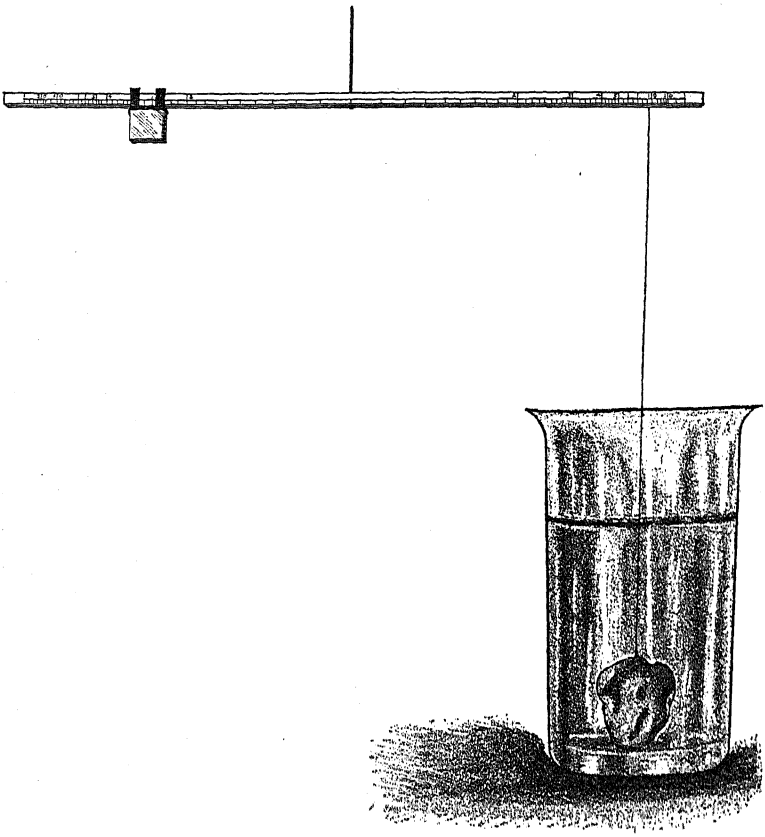
(New York Meeting, February, 1899.)

THE determination of specific gravity dates from such antiquity, and the various published methods of determining it are so numerous, that one may well be skeptical as to the value of a new means of obtaining so well-known a quantity. I make no claim to any great novelty for the little device here described, the principles, though not the convenient details, of which are more or less embodied in the publications of Mr.

William N. Walker, of Dundee, in the *Geological Magazine* of 1883, p. 109, and of Messrs. Leekens and Coats in the *Philosophical Magazine* of 1821, pp. 108, 109, to which my attention was drawn after I had made the instrument.

My desire is to render a service to explorers and prospectors, who go to more or less inaccessible parts of the earth, and to

FIG. 1.



Determination of Specific Gravity by the Density-Rule.

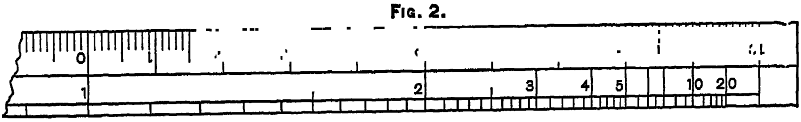
whom any convenient means of determining the nature of the minerals they find is of the greatest possible value. Now the color, crystalline form, hardness and density go a long way towards such determinations, and, with the exception of the last, can be ascertained by observation and the use of a little box (that need not be larger than a pocket match-box), containing the specimens which represent the scale of hardness. The de-

termination of density, however, has necessitated hitherto the use of a balance or other cumbersome apparatus; and my purpose is to replace this by a very light and convenient little instrument, no larger than a pencil, that may be carried in the pocket without inconveniencing the traveler.

A three-sided ivory rule, 21 centimeters long and 0.5 centimeter in width of side, is engraved on one side with a centimeter-scale, from 0 to 10 at the center, and again from 0 to 10 from the center to the other extremity, leaving half a centimeter over at each end. On another side is a scale of density, constructed so that the value at any point is always obtained by dividing the whole length from the center to the extremity by the distance from this point to the extremity. In the center of the rule is drilled a hole, through which a cord is passed; and the rule must balance when suspended by this cord, with the two engraved scales upwards.

A brass bob, 10 grammes in weight, is made so that it can

FIG. 2.



DENSITY SCALE, FULL SIZE.

slip on the rule. It has two openings to permit the reading of either scale, and at the center of each of these openings is an index-mark, which must also be at the centre of weight of the bob.

To make a density-determination, select a specimen somewhat over 10 grammes in weight; place the brass bob with the index-marks at zero on the density- and millimeter-scales; suspend the specimen by a horse-hair or silk thread from the other arm, at any point where it will exactly counterpoise the bob, and fix it there, which may conveniently be done by having a running loop on the horse-hair. Now immerse the specimen in water, and move the brass bob back until it again counterpoises the specimen. On the density-scale the index of the bob will show the density of the specimen, with accuracy to the first place of decimals for any ordinary specimen, from a density of from 2 to 5. From 5 up to 10 it will read to half a unit; and thereafter it is only approximate, but will show

roughly, for instance, whether gold be "good" or "bad" in fineness.

The principle is obvious. If the bob, whether it be of 10 grammes or any other arbitrary weight, counterpoise the specimen when at some fixed point on the other arm, and, after moving inward, again counterpoise the specimen when immersed in water, obviously the distance that the bob is moved inward represents the loss of weight in water; and this distance bears the same ratio to the length from the center to the extremity of the scale as the weight of an equal bulk of water bears to the weight of the specimen. If the specimen tested weighs less than 10 grammes, sufficiently accurate results can be obtained by using any little pebble suspended from the other arm as a counterpoise in place of the brass bob.

Table I. gives the position of the points that should be engraved on the density-scale in centimeters from the end of the scale, and will be of use to any one making an accurate scale with a dividing-engine.

TABLE I.—*Graduations for a Density-Rule.*

Specific Gravity Mark.	Distance from the End in Centimeters.	Specific Gravity Mark.	Distance from the End in Centimeters.
1.1	9.091	.4	2.941
.2	8.333	.6	2.778
.3	7.692	.8	2.632
.4	7.143	4.0	2.500
.5	6.667	.2	2.381
.6	6.250	.4	2.273
.7	5.882	.6	2.174
.8	5.555	.8	2.083
.9	5.263	5.0	2.000
2.0	5.000	.5	1.818
.1	4.762	6.0	1.667
.2	4.545	.5	1.538
.3	4.348	7.0	1.428
.4	4.167	8.0	1.250
.5	4.000	9.0	1.111
.6	3.846	10.0	1.000
.7	3.704	12.0	.833
.8	3.571	14.0	.714
.9	3.448	16.0	.625
3.0	3.333	18.0	.556
.2	3.125	20.0	.500

Table II. gives a few densities taken by the rule, and also accurately determined by a more elaborate method, from which it will be seen that the former determinations are close enough

to satisfy the requirements of a prospector, especially when it is considered that they can be made with ease at the rate of more than six in a minute.

TABLE II.—*Densities by the Rule and by Weighing.*

Specimen.	[illegible]	Specific Gravity by Weighing.
Blende	4.0	3.93
Magnetite	5.0	4.84
Galena	8.0	7.45
Quartz	2.6	2.63

Fig. 1 shows the position of the specimen and bob, at the moment of the final weighing in water, after the bob has been moved into its new position. In Fig. 2, the scale on one arm of the rule, drawn to actual size, is also given for the convenience of those who desire to make a rough scale of the kind, and have not the means at hand to get it accurately divided.

The Liberty Bell Gold-Mine, Telluride, Colorado.

BY ARTHUR WINSLOW, KANSAS CITY, MO.

(New York Meeting, February, 1899.)

Location.—The Liberty Bell gold-mine is in the San Juan region, in the southwestern corner of Colorado. It is situated about 2 miles from the town of Telluride, near the summit of the Uncompahgre range, at the head of Cornett basin, at an altitude of 11,000 feet, and in a district of excellent record in the past and of great promise for the future. In the immediate vicinity are such well-known and important mines as the Smuggler-Union, with a total production of over $12,000,000; the Virginius and Revenue Tunnel group, with a production of probably $5,000,000; the Tom-Boy, with a production of probably at least $3,000,000; the Japan, the Cimarron, and a number of others.

History.—The first prospecting in this district is reported to

have been in 1875,* in which year the Smuggler vein was located. Other locations were made at about the same time; small lots of ore were shipped out, and a limited amount of milling was done; but little could be accomplished under the then existing conditions. At the beginning, the nearest railway point was some 250 miles distant, and only the richest ores could be profitably mined. In July, 1881, the narrow gauge railway was completed into Durango, and in December, 1887, the line from the north was completed into Ouray. It was not, however, until the year 1890 that the Rio Grande Southern was commenced; and this road reached Telluride early in 1891. As the district became more accessible and transportation difficulties were lessened, the mining industry grew, capital became interested, and by degrees the production has reached its present proportions.

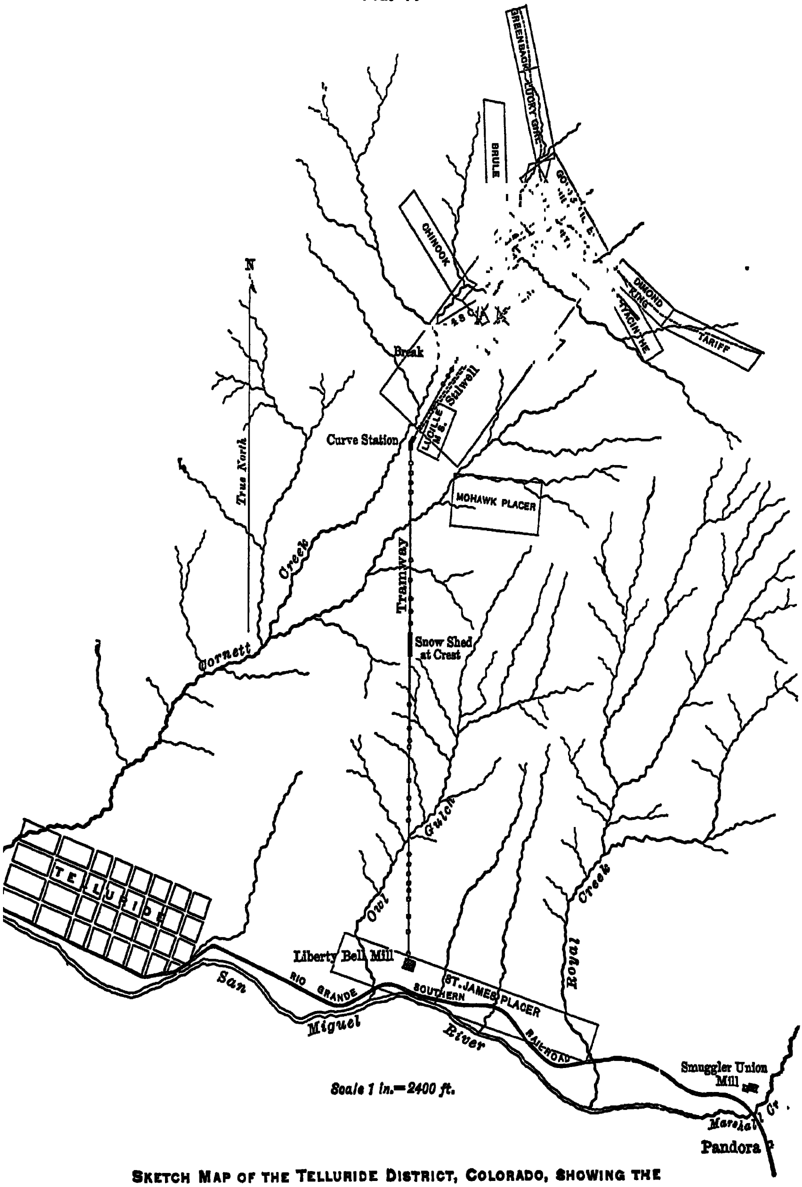
The vein of the Liberty Bell group was one of the first discoveries. Its early history is interestingly related in the following extracts from a letter kindly written to me by Judge C. H. Toll, of Denver, one of the original owners:

"In answer to your letter of inquiry, I beg to say that, in the spring of 1876, I entered into a prospecting-arrangement with Mr. William L. Cornett, under which Mr. Cornett was to go into the district at the head waters of the San Miguel river and to spend the season there in prospecting for our joint account. . . . . Mr. Cornett left Del Norte about the 1st of June, well outfitted with horses and burros, and went directly to what is now the town of San Miguel, a mile or so below Telluride; and on the 10th of July he discovered and located, in his name and mine, the Gold and Silver Chief claim, discovered at the point where the discovery-shaft was located, near the easterly end of the claim. The claim, as originally located, extended 750 feet in each direction along the vein from the point of discovery; but in 1879 I had my engineer amend the location so as to leave the southeasterly portion of that claim open; and upon that portion my engineer located the Hyacinthe claim, extending 1500 feet in a southeasterly direction from the easterly end of the Gold and Silver Chief claim. At the point where Mr. Cornett discovered the vein, the vein was crossed by a mountain stream, which has ever since been known as Cornett creek, and which, in the spring-time, carries a considerable volume of water. By the action of the water the country-rock on the lower side of the vein had been cut away, so that, when I visited it in August of 1876, the vein was exposed on the lower side for about 6 feet in height, and at points particles of free gold were exposed where the action of the water had worn and polished the quartz. At that point the vein was nearly 10 feet in width. Although at the time of my visit very little develop-

* "Preliminary Report on the Mining Industries of the Telluride Quadrangle, Colorado," by Chester Wells Purington, 18th *Annual Report U. S. Geological Survey*, 1896–1897, Part III., *Economic Geology*, p. 745.

ment-work had been done upon the claim, the property had become quite well known in the camp; and both Mr. Cornett and I were very hopeful that it would soon become a producing property. I had then been in Colorado only a few

FIG. 1.



SKETCH MAP OF THE TELLURIDE DISTRICT, COLORADO, SHOWING THE LIBERTY BELL MINE, TRAMWAY AND STAMP-MILL.

months, and neither Mr. Cornett nor I realized how much capital would be required in the construction of a tramway, a mill, and the improvements essential to a developed and producing mine. In 1879 Mr. Cornett disposed of his interest,

and from October, 1879, until its purchase by the present company in 1898, the property was owned by former U. S. Senator Frank Hiscock and Hon. W. H. Gifford—both of Syracuse, New York—and myself.

"In the winter of 1879 and 1880 the upper cross-cut tunnel, 140 feet in length, was run by Mr. S. P. Norton under contract, and the vein was cut at a depth of about 125 feet, and the development of the vein by levels from the intersection of the tunnel and the vein was commenced. At that time the mine was something more than 200 miles from the nearest railroad-point, and some idea of the cost of mining operations in that vicinity may be drawn from the fact that the contract-price of the tunnel was $16 per foot, which barely paid the expense of the work, although Mr. Norton was a skilful and experienced miner. In the year 1881 Messrs. Hiscock, Gifford and I applied for a U. S. patent for both claims, as well as for two mill-site claims in connection therewith, but the patents were not issued until February 21, 1884."

The exposure referred to by Judge Toll as the point of discovery is visible at the present day. By reference to the map, Fig. 1, it will be seen that the apex of the vein does not pass through the two extreme end-lines of the Chief and Hyacinthe claims, but cuts diagonally across the two claims, so that only about 1000 feet of the apex was covered instead of 3000 feet, as was intended—with consequent serious loss to the original owners. The location was plainly a blunder, caused by a failure to take into consideration the effects of an irregular topography upon the position of the apex-line, a common mistake of the average locator. The strike of this vein is regular and the claims are parallel with the strike, but the mountain rises on both sides of the Chief claim; and consequently the outcrop is thrown farther and farther to the north. Apparently, other locators perceived the mistake, and the Liberty Bell and Dimond King claims were subsequently located to cover the apex where it passed out of the side-lines.

I first visited the camp in the autumn of 1896, coming over the range on horseback by the Virginius pass from Ouray. I was immediately interested in the appearance of the camp; and various properties were examined and developed by me, in the interest of the United States and British Columbia Mining Company, during the following autumn and winter months. My first inspection of the Liberty Bell vein was not made, however, until the spring of 1897. The various claims covering the vein were then held by four different groups of owners, and the interests in different groups were sometimes as small as one-sixteenth. Considerable development-work had already

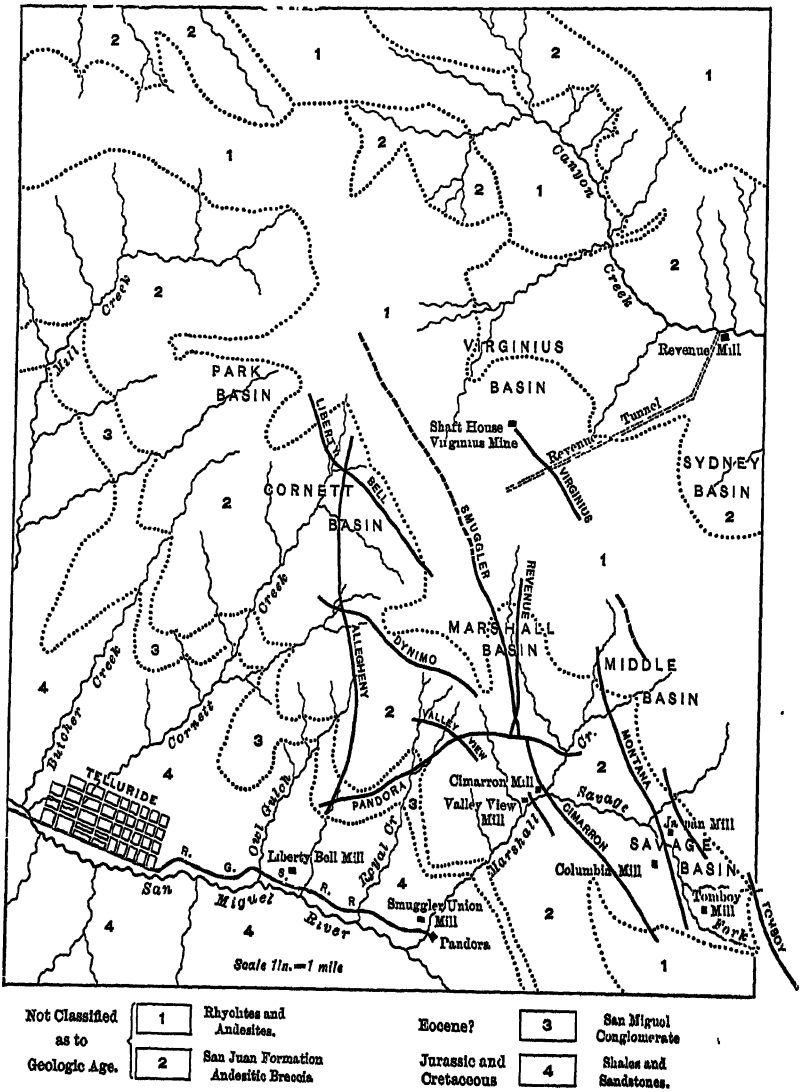
been done in years past by the owners, especially in the Gold and Silver Chief and Hyacinthe claims, where the main level was about 800 feet long. Small lots of sorted ore had been shipped to smelters; and one lot of about 1000 tons had been packed down the mountain and milled in a local stamp-mill. Under the then existing conditions, however, no profit could be realized.

On my first inspection, I was struck by the boldness and persistence of the vein. It was evidently a strong fissure which would maintain itself in length and depth. The preliminary samples, and the later larger and more systematically collected samples, did not yield the values claimed by some of the owners or reported from the various shipments and mill-runs. Still, sufficient was shown to indicate a profit from working on a large scale with economical and labor-saving methods. Before any definite steps could be taken, however, the properties had to be consolidated and the title perfected in many ways. This was no easy task in view of the multitude of owners, some of whom were very bitter in their feelings towards each other. The necessary negotiations occupied nearly eight months; but they were finally completed, and all the lode-claims were brought under control by bonds and leases of the usual form. In addition, a tunnel-site and various other claims were located. We were particularly fortunate in being able to purchase, for a mill-site, the St. James placer, a tract of some 30 acres, in the valley above the town of Telluride, traversed by the Pandora branch of the Rio Grande Southern railway. Water-supply and power were obtained by purchase of the Deer Trail water-right, opposite the mill-site. All things considered, the location of the mill is one of the best in the district, being in the valley of the San Miguel river, where snows are never heavy, and there is no danger of snow-slides; on the south slope of the hill, where the full effect of the sun is enjoyed; and immediately on the railway-line, within three-quarters of a mile of the town.

Geology and Vein-Formation.—The geology of the country in the vicinity of the mine is shown in the map, Fig. 2, which has been compiled from the sheet of the U. S. Geological Survey, accompanying Mr. Purington's report, already re-

ferred to—supplemented by certain surveys of our own. The andesitic breccia, called the San Juan formation, is the principal ore-horizon of the camp. Some veins can be traced through

FIG. 2.



GEOLOGICAL SKETCH-MAP OF TELLURIDE DISTRICT, COLORADO.

the upper lava-flows, but others are only faintly expressed in these "cap"-rocks, where they are split into a number of seams or leads, which may or may not be ore-bearing, so that some

of the veins have very obscure apexes. None of the more important veins in the mountain-range north of the San Miguel river have been exploited in the formations below the San Juan breccia; but veins are operated in the lower formations on the Ouray side to the north, and in Bear Creek basin to the south. Therefore, though the question is open as to whether these veins will continue and will be ore-bearing in the lower rocks, the chances seem to favor an affirmative answer.

The San Juan formation is principally a bluish-gray breccia, angular and subangular fragments of andesite, with a bluish matrix of the same material. It varies in thickness from 2000 to 3000 feet. Mr. Whitman Cross,* who has studied these rocks extensively, as part of his work for the U. S. Geological Survey, describes the formation as composed of fragments, ejected from one or more volcanic centers, which received their stratified arrangement in the waters of a lake, and possibly also through falling in showers on slopes adjacent to the volcanic vent.

The veins of the district are remarkable for their strength and prominence. Widths of 5 and 6 feet are common. From a summit north of Marshall basin the croppings of the principal veins can be traced by the eye for distances of a mile or more. They are marked by a discoloration of the surface, and, where one crosses a ridge, it occupies almost invariably a saddle-like depression, the result of more rapid weathering along the vein-fissure.

The Liberty Bell vein shares these characteristics. Where not covered by *débris* or slide-rock, its course can be plainly traced through the Lucky Girl and Greenback claims; and there is a decided depression in the mountain-ridge where the vein crosses. In the Tariff claim, on the southeastern end of the property, the apex is obscured in the rhyolite cap-rocks. The strike of the vein is uniform and nearly exactly N.W. to S.E., with a dip of about 60° S.W. The width varies from 3 to 8 feet or more. The walls are well-defined and sometimes smooth and slicken-sided; but, as the country-rock is not generally very hard, the latter are not common characteristics.

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* *Proc. Col. Sci. Soc.*, Sept. 7, 1896.

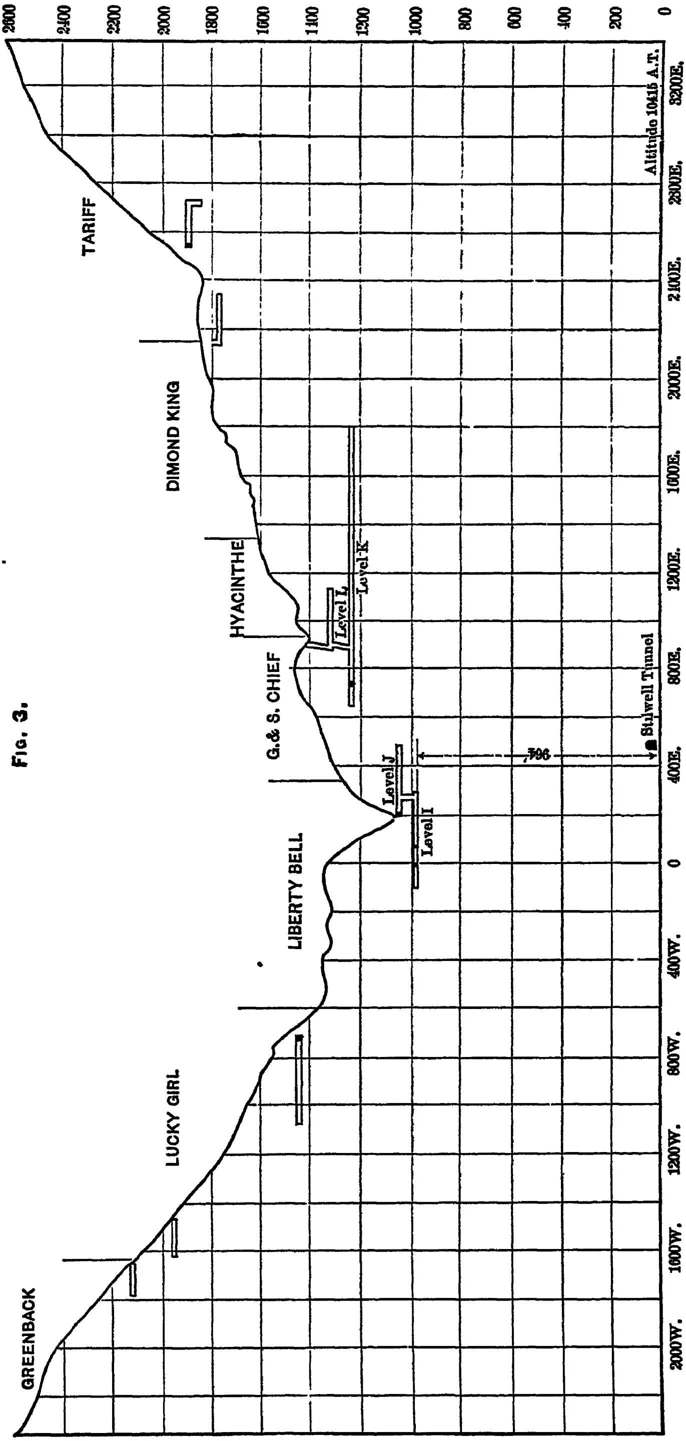
Ore Composition and Values.—The vein-material consists of quartz and silicified earthy matter, in bands or layers, between which are layers of soft "gouge" or clay, the latter often of a dark-brown or black color; such are generally found on the foot or hanging walls. The quartz layers are sometimes hard and dense, and sometimes shattered and friable. No comb-structure or regular banded arrangement can be recognized, though drusy surfaces of quartz are sometimes seen. Calcite is found in places in irregular masses. A greenish slaty gangue is almost always present, and sometimes occupies nearly the whole vein-space. It is an earthy material, probably derived from the attrition of the country-rocks when the vein-fissure was formed, and it is often silicified; it generally contains pyrite diffused through it in minute grains, but is practically valueless. Pyrite is diffused through the other vein-rocks also, and, together with particles of iron and manganese oxides, constitutes the bulk of the concentrates. Other metallic minerals are rarely seen. Free gold is occasionally visible in unaltered quartz and also in thin coatings. Some of the black "gouge" runs very high in either gold- or silver-value, but this cannot be counted upon; and, in general, it is almost impossible to distinguish by the eye the valuable portions of the ore, the associations not being constant. Gold has been recognized free in unaltered quartz, as above remarked, and is also intimately associated with the pyrite. The silver in the unaltered ore is probably in the form of a sulphide, combined with arsenic, and possibly some antimony.

The following analysis of a sample of the ore was made by Dr. W. H. Walker, of the chemical department of the Massachusetts Institute of Technology, under the direction of Prof. W. O. Crosby:

Analysis of Liberty Bell Ore.

	Per cent.
Quartz and clay (insoluble residue),	84.44
Calcite,	9.45
Apatite,	0.20
Limonite,	3.30
Pyrite,	0.35
Arsenopyrite (?),	0.24
Bornite,	0.15
Undetermined (C and H_2O, and loss,	1.87
	100.00

Fig. 3.



Profile, showing Workings in Liberty Bell and Neighboring Mines.
Horizontal and Vertical Scale 1 in.=800 ft.

AM. BANK NOTE CO N.Y.

Assuming, as we must, that the limonite and, similarly, the bornite, are wholly secondary and are limited to the oxidized zone, we obtain as the most probable constitution of the wholly unoxidized ore in a dry state:

Quartz and clay (insoluble residue),	84.44
Calcite,	9.45
Apatite,	0.20
Pyrite,	3.60
Arsenopyrite (?),	0.24
Chalcopyrite ($CuFeS_2$),	0.23
Undetermined (C and H_2O) and loss,	1.84
	100.00

Only a trace of manganese was detected in the lot of ore analyzed; but manganese is quite abundantly shown in other lots of ore, especially those associated with the clay or vein-"gouge."

In discussing this analysis, Prof. Crosby remarks that the pyritic minerals are disseminated through the quartz and the slaty gangue. Traversing this mixture of quartz and gangue are numerous veinlets and masses of secondary quartz and calcite. The quartz occurs by itself in well defined veinlets, with very distinct comb-structure, and in vugs, and in part it is more or less intimately mixed with the less abundant calcite. The two minerals are clearly contemporaneous. These occurrences of secondary quartz and calcite are almost entirely free from pyrite or other sulphides. The pyrite, he remarks, is the chief sulphide, and occurs in a very finely divided condition. The arsenic is difficult to locate. It was thought to occur in the unoxidized ore, possibly as arsenopyrite; but that mineral could not be identified by the microscope. Supplementary analyses of concentrates and tailings showed a very strong reaction for arsenic in the latter, but only a trace in the former. This proved that the arsenic was not present to any appreciable extent in the sample analyzed as arsenopyrite or as proustite, or in any other unoxidized form. Prof. Crosby suggests that it is probably present as one of the hydrous arsenates of iron, such as scorodite, which is of sufficiently low specific gravity to prevent ready concentration or separation from the gangue. Traces of proustite may, however, be present. This suggestion is of special importance, and offers, perhaps, an explanation of

the loss of silver-values in the tailings, to which reference will be made below.

Later tests, of other lots of ore, have indicated the presence of some antimony; but this has not been satisfactorily demonstrated. Small amounts of zinc were recognized under the microscope. Tellurium appeared to be wholly wanting.

The value of the ore varies greatly in different places. Cross-section samples gave results ranging from a trace of gold and silver to $100 and more, in the combined value of these metals. Shipment-certificates of lots of sorted ore, which were turned over to the present company with the property, showed values of from $30 to $40. Judge Toll reports the average yield, on the plates, of the 1000 tons of ore milled for him, as about $11 per ton. As an illustration of the irregularity of the distribution of values and of the consequent discrepancies in sampling, the following table is given. It shows the widely different results obtained from different parts of one stock-lot of ore. This stock-lot was composed of a mixture of large samples of ore taken from various parts of the mine. The bulk at the beginning was about 1½ tons, all broken down to about a half-inch mesh; this was mixed and quartered twice, leaving a pile of about 800 pounds, and this was quartered and separated into the different portions listed below:

	Gold. Oz.	Silver. Oz.	Total value.
Sample retained at mine,	0.37	4.57	$9.80
Sample used in cyanide-test,	0.69	1.90	15.70
Samples used in pan-amalgamation-test,	0.39	4.00	9.80
	0.89	3.20	19.40
Samples used in Wilfley table-test,	0.30	4.20	8.10
	0.20	2.80	5.40
Sample used in McCoy table-test,	0.52	4.08	12.40

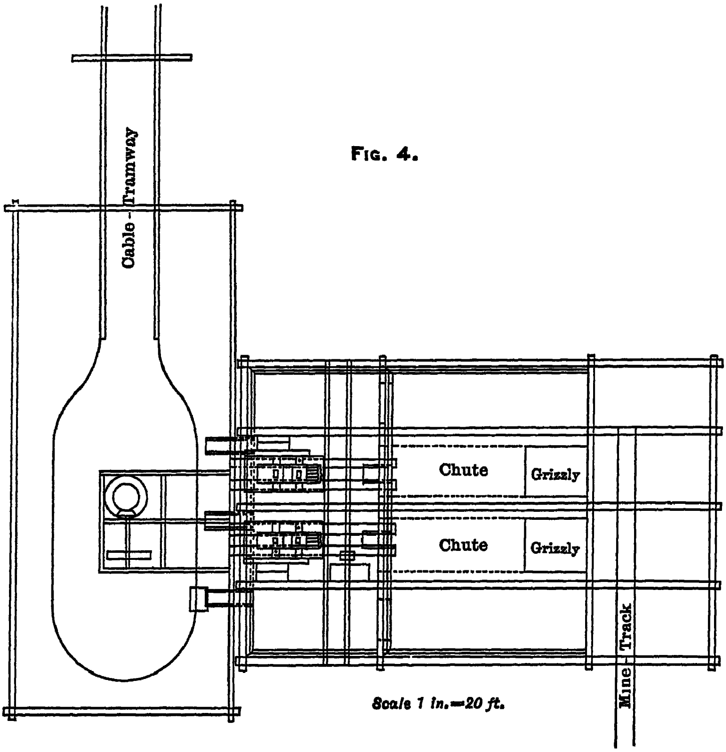
The first thorough examination of the property included a systematic sampling throughout all levels. This was done in duplicate under different supervision. The method pursued was to break down and catch on canvas large quantities of material, at regular intervals across the entire section of the vein. Each lot was then roughly broken down and quartered, yielding samples of from 25 to 150 pounds.

After obtaining the results of this sampling, extensive develop-

ment work was undertaken, accompanied by sampling as the work proceeded. Before the property was finally accepted, and plans for working were decided upon, fully $30,000 had been expended. The results proved the vein, so far as developed, to be practically one continuous chute of low-grade ore for a distance of about 2000 feet.

Ore-Treatment and Milling-Methods.—Early in the examination

FIG. 4.

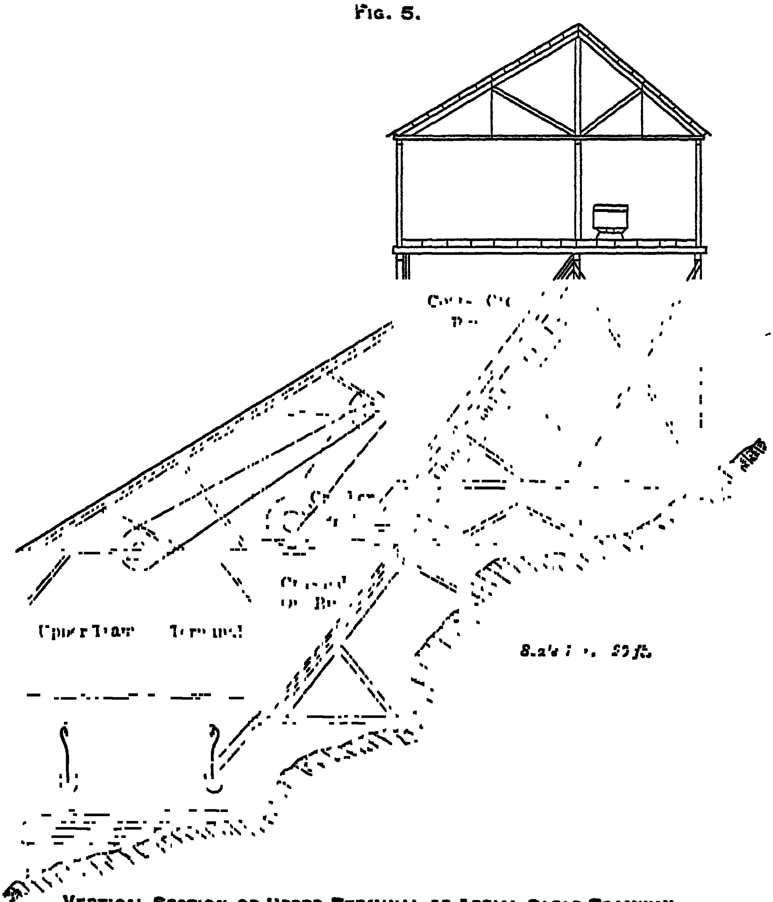


PLAN OF UPPER TERMINAL OF AERIAL CABLE-TRAMWAY, LIBERTY BELL MINE, COLORADO.

of the property it became plain that the success of the undertaking would depend in large part upon the adoption of a cheap and efficient method of treatment. The results of the numerous assays showed that the values were about two-thirds in gold and one-third in silver. Preliminary amalgamating-tests indicated that the larger part of the gold was free-milling, and that probably 70 to 80 per cent. of the gold could be saved on the plates, and by ordinary concentration-methods. With the sil-

ver, however, the reverse was the case; only a small fraction of the total could be caught by amalgamation, and not much more by panning. Tests on a large scale were then undertaken, including stamp-mill runs of several lots, aggregating 45 tons, with vanners and "Triumph" tables for concentration. Cy-

FIG. 5.



VERTICAL SECTION OF UPPER TERMINAL OF AERIAL CABLE-TRAMWAY, LIBERTY BELL MINE, COLORADO.

anide-tests on both raw and roasted ore were also made; a lot of about 200 pounds was treated by pan-amalgamation, and special lots were tried on other concentrating-tables.

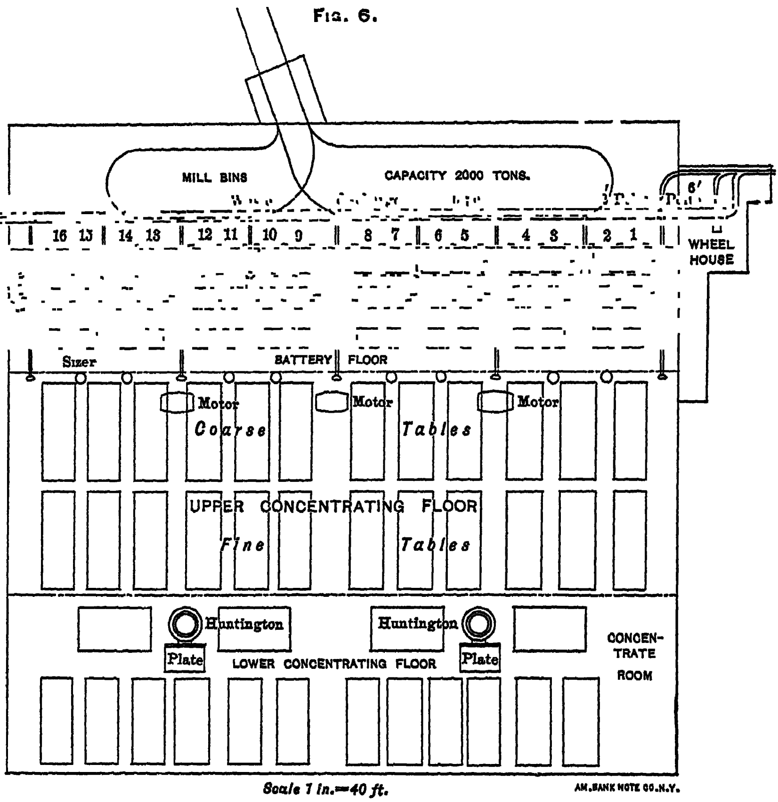
The stamp-milling and concentrating-tests gave savings varying from 54 to 78 per cent. of the gold, and from 14 to 30 per cent. of the silver. The loss of silver was still excessive, and

that metal seemed to be in an elusive form which no ordinary concentrator would save.

Cyanidation gave an extraction on raw ore of about 85 per cent. of the gold and about 50 per cent. of the silver. On roasted ore the extraction was smaller.

Concentration by panning, followed by a cyanidation of the tailings, gave a saving of 50 per cent. of the gold and 15 per

FIG. 6.

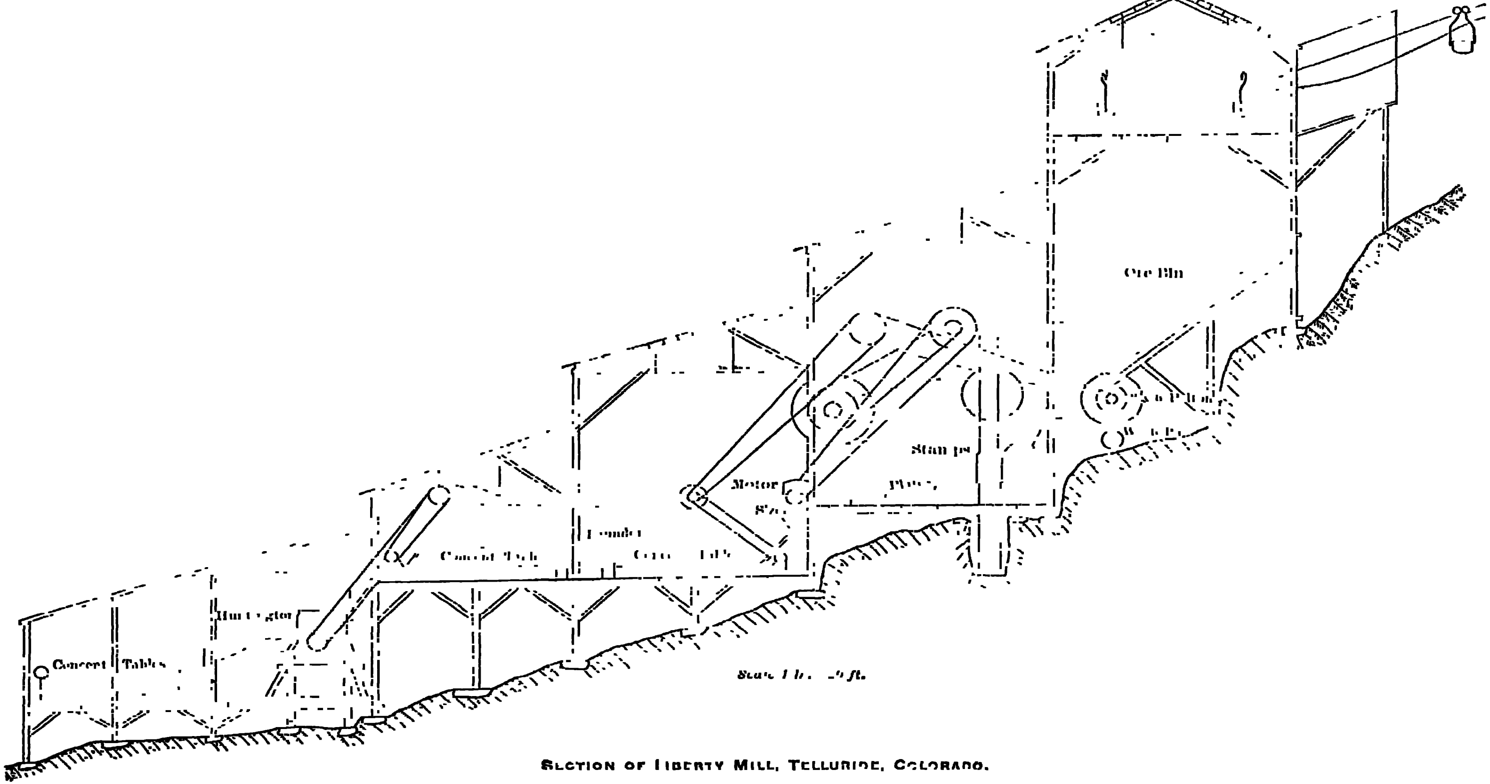


LIBERTY MILL, AS DESIGNED FOR 80 STAMPS.
PLAN.

cent. of the silver in the concentrates; and the extraction from the tailings by cyanide-solution amounted to 36 per cent. of the gold and 54 per cent. of the silver, or a total of 86 per cent. of the gold and 70 per cent. of the silver.

Pan-amalgamation gave a saving of from 64 to 82 per cent. of the gold and from 31 to 42 per cent. of the silver; and amalgamation combined with cyanidation gave a saving of 76 per cent. of the gold and 44 per cent. of the silver.

Fig. 7.



Section of Liberty Mill, Telluride, Colorado.

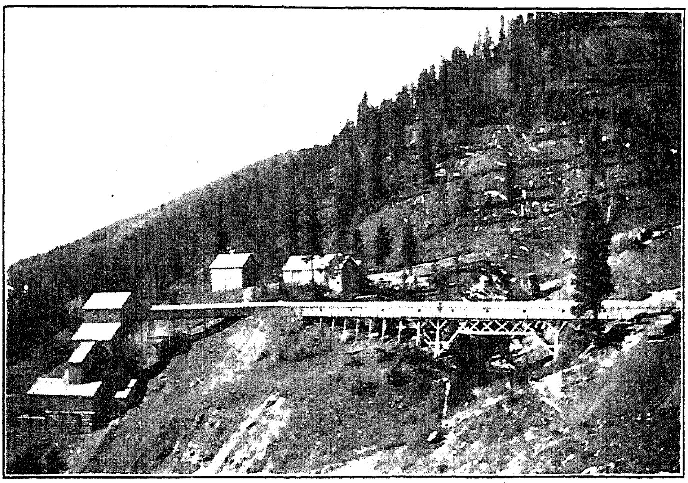
After a careful study of the results of these different tests, due consideration being given both to percentages of saving and to costs of treatment, a combination-process of stamp-milling, followed by concentration and a supplementary slime-treatment, seemed to be the best. The mill has therefore been planned, and the first operations have been conducted, along that line, though the supplementary slime-treatment is still under investigation.

The amalgamation, so far as it goes, is very free and quick, the first of the three apron-plates catching, probably, 80 per cent. of the total product from these plates. The runs, so far, show that about 65 per cent. of the gold, but only about 5 per cent. of the silver, can be saved on the battery-plates. The amalgam is of exceptionally low grade, yielding only about 20 per cent. of bullion, which has a fineness of about 560 gold and 420 silver. A number of tests showed that there was no advantage from inside plates in the mortars. Quicksilver is fed to the mortars, but very little amalgam is collected from the mortars in the clean-up. A 20-mesh screen has been used with a double discharge-mortar, and a daily crushing-capacity of 5 tons per stamp has been reached at times. Even a larger-mesh screen has given good amalgamating results, and a 16-mesh pattern may be decided upon for future use.

The concentrates saved, in runs so far made, with single concentration, vary under normal conditions from 1 in 40 tons to 1 in 80 tons of the ore stamped. The value of these concentrates ranges from $40 to $60 and sometimes more, per ton, in which values the gold and silver are about equally represented. Thus, at best, only about 5 per cent. of the total gold and about 15 per cent. of the total silver has been saved in the concentrates.

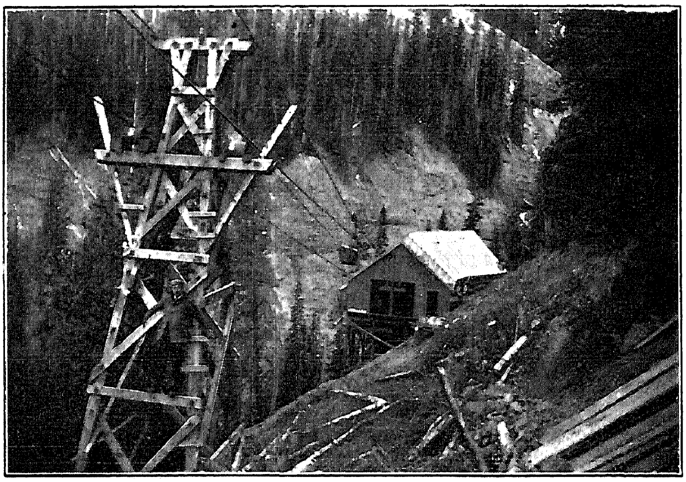
From these figures it appears that the entire saving by amalgamating and single concentrating is about 70 per cent. of the total gold and 20 per cent. of the total silver. The silver-extraction is thus decidedly unsatisfactory. The more recent runs, with careful adjustments, showed some improvement; and with the system of double concentration, now being arranged for, there will be, undoubtedly, further gain; but the tailings will probably still run high, and may exceed $3 per ton in value, of which the greater part will be in silver. The values

FIG. 8.



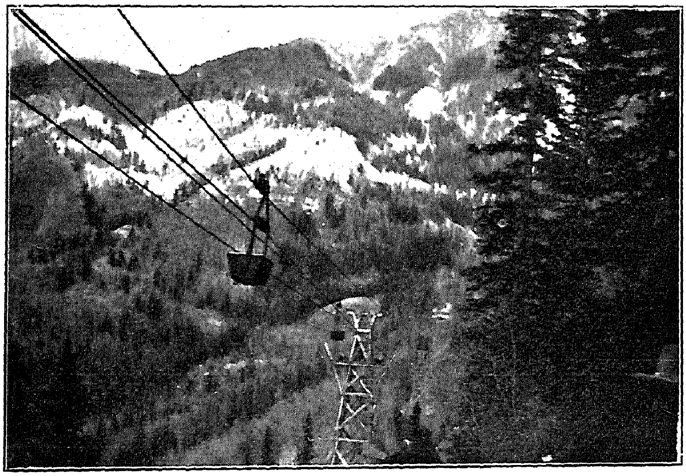
TRESTLE AND CRUSHER-BINS AT UPPER TERMINAL.

FIG. 9.



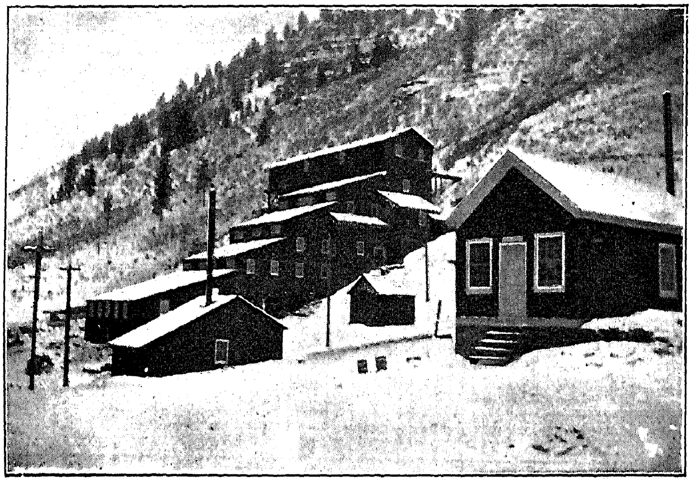
TRAMWAY-TOWER AND CURVE-STATION.

FIG. 10.



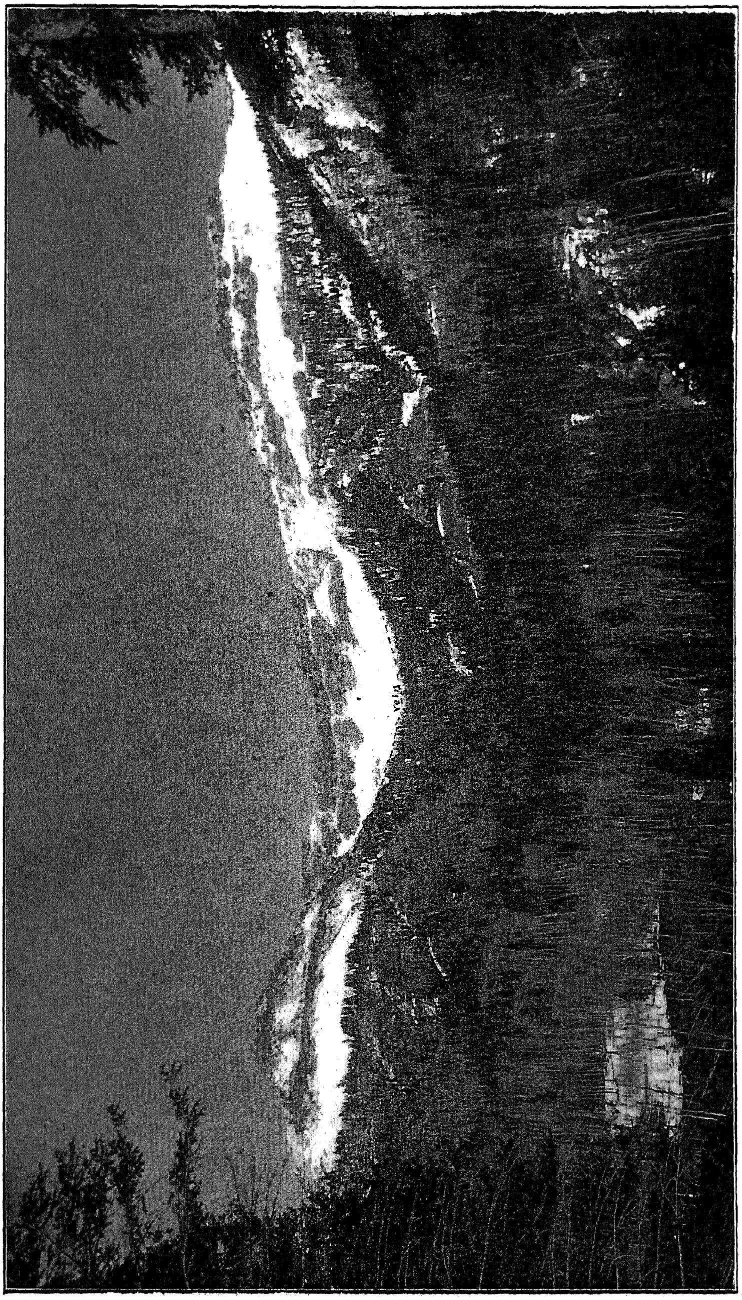
SECTION OF CABLE-TRAMWAY IN OPERATION.

FIG. 11.



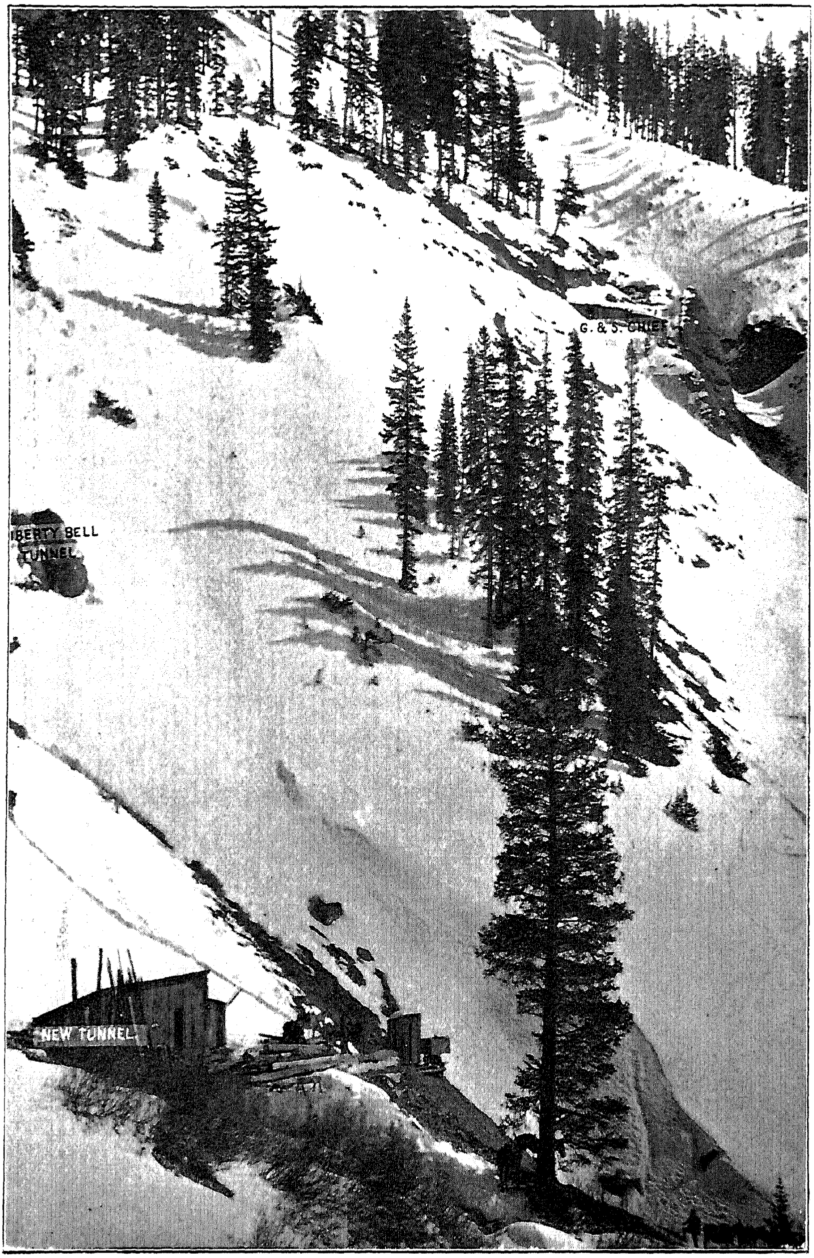
FIRST SECTION OF MILL.

FIG. 12.



GENERAL VIEW, OF CORNETT BASIN, TELLURIDE, COLORADO.

FIG. 13.



GENERAL VIEW, SHOWING LOCATION OF TUNNELS.

in the tailings seem to be nearly uniformly distributed in both the coarse and the fine product; but the silver predominates in the latter, which is of the character of a cream. Tests on stationary canvas-tables have yielded results of some promise, but they are not entirely satisfactory. Leaching-tests suggest a possible solution, but a difficulty to be met here will be in obtaining a satisfactory percolation, and agitation may be necessary. The problem is undoubtedly a difficult one; and its solution means a great deal, not only to the Liberty Bell Gold Mining Company, but possibly also to other large mines in the neighborhood, where even greater silver-values are flowing away in the tailings. Others, as well as the writer, will therefore be very glad of any discussion to which this paper may give rise, and be grateful for any criticisms or suggestions from members of the Institute who may have had similar problems to solve.

Mining Methods.—The mining methods adopted are those usual in any large fissure-vein. The vein is wide and contains much soft material, and is consequently easily mined, one man being able to break down at times 8 or more tons per shift. The levels are timbered with stulls and hitches, and often with square sets. Stulls are placed at frequent intervals in the stopes, and such waste as is made is allowed to pile up on the lagging and stulls over the level. The facilities for tunnel-mining are excellent. During the winter of 1898 a cross-cut 230 feet long was driven at what is designated as level "I." (See section, Fig. 3.) This is 100 feet below the lowest apex and about 1600 feet below the highest point reached by the vein in the property. From this cross-cut the ore will be trammed in trains of several cars directly to the crusher-bins. Early in the negotiations for the purchase of the property, a tunnel-site was located, from which the lowermost tunnel will tap the vein at a distance of about 2600 feet horizontally from the adit-mouth, and over 900 feet on the slope of the vein below level "I." The turn-station of the cable-tramway is at the mouth of this tunnel; and, after the latter shall have been completed, the ore will be delivered to the tramway at this point, and the upper section of the tramway can be abandoned.

Equipment.—Operations for the proper equipment of the property began early in the spring of 1898. In general terms,

this equipment consists of boarding- and bunk-houses at the mine; a trestle and snow-shed, about 400 feet long, from the tunnel-mouth to the crusher-bins; a 2-mile cable tramway, built by the Mine and Smelter Supply Co. and similar to the Bleichert tramway of the Trenton Iron Works, with upper and lower terminals and a turn- and a tension-station; and a mill at the lower end of the tram, with office, assay-laboratory, etc. A sawmill was established at the mine, during construction, in order to utilize the timber on the ground. The upper terminal is illustrated in plan and section in Figs. 4 and 5. The crushers are located here, away from the mill, with the idea of saving wear and tear on the tramway by furnishing only crushed ore to the buckets. Fig. 8 is a view of the trestle and crusher-bins at the upper terminal. One sectional crusher of the Blake type, 11- by 18-inch jaws, is now installed, and place has been allowed for an additional crusher of the same size. Fig. 9 shows the tramway-tower and curve-station (see Fig. 1); and Fig. 10, a section of the tramway in operation. Gearing is provided for utilizing the power developed by the tram for crushing the ore. This is supplemented at present by a steam-plant, and an electric motor will probably be put in later.

The mill, illustrated in plan and section in Figs. 6 and 7, has an excellent hill-side location, with a fall of about 60 feet from the top of the bin to the lowermost concentrating-floor, which latter is about 10 feet above the proposed railway-switch. The mill is being built in sections, a plan which permitted the early starting of productive operations, and also the perfecting of details before the complete plant is installed. It is designed for 80 stamps, in 16 batteries, as shown in Fig. 6. A view of the first section (20 stamps), already completed, is given in Fig. 11. The crushed ore is delivered from the tram directly into a large storage-bin running the whole length of the mill. This bin is about 25 feet high and will be 140 feet long, with a capacity of about 2000 tons. The ore is delivered from the bin to the stamps by chutes and automatic hanging feeders of the Challenge type. The mortars are deep and narrow, of Homestake pattern, and with double discharge. The total weight of the stamps is 850 pounds and the drop is 7 inches. The three apron-plates of the first 20 stamps have an aggregate length of 12 feet, and are each 54 inches wide. The

next 20 stamps will probably be equipped with still wider plates. From the plates the pulp passes through hydraulic sizers to the first concentrating-floor. From the first series of concentrators the coarse tailings will be taken to a Huntington mill for re-grinding, and thence over a second series of plates to the second concentrating-floor. The fine tailings from the first concentrating-floor and the entire tailings of the second concentrating-floor will probably be subjected to some further slime-treatment.

The mill is operated by water-power, supplemented by electricity. One 6-foot and one 2-foot Pelton wheel have been installed. The latter is used exclusively for the concentrating-tables. The water is obtained from Deer Trail creek, and is conveyed to the mill through an 8-inch pipe about 3000 feet long. The working-pressure is over 350 pounds per square inch. The flow of water varies from a minimum of about 150 gallons to a maximum of about 1000 gallons per minute. It thus furnishes a large amount of power during part of the year, but from the late summer gradually diminishes to barely enough to run 5 stamps and the concentrating-tables. In order that all of the water may pass through the wheels, a large 2-foot tail-race from these wheels is conducted the whole length of the mill immediately beneath the ore-bins, and is tapped at intervals to supply the batteries and concentrating-tables. This tail-race thus acts as a tank or storage-reservoir for the mill, with a constant pressure.

Electric power is furnished, at a contract-rate per month, by the Telluride Power Transmission Company. The mill and the other buildings are heated by steam; a separate boiler has been installed for that purpose some little distance from the mill, so that there is no danger from fire.

Fig. 12 is a general view of Cornett Basin, and Fig. 13 is a view of the Liberty Bell ground, showing the location of tunnels.

Iron Ores of the Potsdam Formation in the Valley of Virginia.

BY CHARLES CATLETT, STAUNTON, VA.

(New York Meeting, February, 1899.)

SOME years ago the writer was struck by what might be called the remarkable vitality of the Virginia furnaces during the panic of 1893; and attention was called to the fact in the *American Manufacturer* of February 8, 1895. From the second half of 1892, which was a period of maximum output, to the second half of 1893, when the full effects of the depression had been reached, the output of pig-iron had fallen off in Illinois 85; in New York, 66; in Ohio, 51; in Tennessee, 44; in Pennsylvania, 28; and in Virginia only 15 per cent. It seemed a reasonable inference that the State which had thus shown its marked ability to meet hard times could make and market its product with a larger margin of profit than any of the other States. This was true at that time, and to a certain extent the reasoning still holds good; but my mistake was in not fully realizing the marked effect of the Mesabi development, combined with reduced economies in transportation, and the consequent advantage to those furnaces which were so situated as to utilize these new commercial factors.

The effect of these factors is seen in comparing the second half of 1894 with the second half of 1892. New York had dropped off 44, Alabama 23, Tennessee 21, Illinois 19, and Virginia 16 per cent., while Pennsylvania had increased 5 and Ohio 10 per cent.

While there is no question of the great economy which has been made possible for certain interests which are peculiarly situated with reference to the ores of the Northwest, it is yet too early to say what furnaces not so fortunate will have to pay for their raw material. Already an increase of twenty cents per ton of ore has been announced, based upon increased cost of production.

It is at least a fact of interest that a large number of the Virginia furnaces, practically without a home market, have managed to peg along for a great many years, through sunshine and shade, without a break, and apparently able to adapt themselves to the changed condition of the times. How well this has been done will be inferred from the statement made in December, 1898, before there was any increase in the price of iron, by the president of one of these companies, that "if the price and volume of business would but continue stationary he would be satisfied."

With few exceptions the furnaces which have been in operation have owned their own ore-supply, at or near the site of the furnace. They thus eliminated the profit in ore-mining, but discouraged the development of mines to supply the general market, as the ores are not of a kind to justify shipment into other districts. The question naturally presents itself, how long will this condition continue? Either the present furnaces have an abundant supply of ore to last during the usual life of a furnace—in which case there is good reason for the construction of other furnaces on similarly situated but undeveloped property—or the supply of ore connected with the furnaces in operation is becoming less abundant, and it will be necessary for them to secure a supply from other sources. In either event, unless there is a marked change in development in some direction not now anticipated, the undeveloped ore-properties in Virginia will probably shortly find a market.

The question of ore-supply is not simply one of ultimate quantity, but is as closely associated with the questions of quality and cost of mining and transportation. If ore cannot be furnished at the furnace at a figure which will permit the manufacture of iron at less than the market-price which then exists, or may be expected to exist over a considerable period of time, then the ore-deposit is practically valueless for the present as a source of supply. If an ore runs high in manganese it is not an "ore" with reference to a furnace whose established market is for high-grade foundry-iron; and an ore running high in phosphorus will not meet the requirements of a furnace which has a market only for pig-iron containing a small amount of this ingredient.

Having had occasion, a few years ago, to investigate the

available ores north of a certain line in Virginia, I am led to offer the following notes regarding the deposits found in the Potsdam formation, along the eastern side of the Valley of Virginia and north of Roanoke, as possibly throwing additional light on their character and extent.

These ores have been discussed in the *Transactions*, and are well known to many of the members of the Institute. The following brief description of their general nature and relations will therefore be sufficient:

General Description of the Potsdam Ores in Virginia.

The Blue Ridge consists, in ideal section, of the older crystalline rocks to the east, which are overlain by flags and conglomerates and sandstones, with heavily-bedded white quartzite ridges commonly marking its western border. Overlying this quartzite, and usually (by reason of their soft character) occurring only as foot-hills, are heavy beds of clay and partially decomposed shale. These are in turn overlain by the characteristic limestone of "The Valley."

The irregularities in thickness, folding and erosion bring the older rocks close to the valley, at some places, while at others they are separated from it by a very great expanse of the stratified formations.

All of the formations above referred to contain more or less iron ore, but only one will be considered in this connection.

The heavy clays and shales referred to as overlying the quartzite are the repository of beds of iron ore, which, by their extent and persistency, mark this as one of the two greatest ore-bearing formations in Virginia. The ores of this formation are found over a distance of 150 miles or more, in a greater or less state of development, along a definite horizon. The soft nature of the enclosing strata, and the absence of any distinctly marked foot- or hanging-wall, have no doubt contributed largely to the irregularity of the bed from point to point, and often render exceedingly difficult the determination of its exact position and the problem of its practical development.

Prof. William B. Rogers, founder of the Boston Institute of Technology, author of *The Geology of the Virginias*, and one of the greatest of American geologists, pronounced these deposits "continuous" and "inexhaustible." The U. S. Census-report

of 1880 speaks of them as "continuous beds." Maj. Jed. Hotchkiss says that the variations from point to point are not greater than are found in coal-beds. Prof. William M. Fontaine considers them to be "overlapping lenticular deposits of segregation, which, from the similarity of conditions existing for a long distance, may be found extending along a definite plane." Dr. Andrew McCreath says that they are "geologically co-extensive with the Blue Ridge." The question of their actual continuity may never be definitely settled; for while at points there seems to be the strongest evidence in favor of a continuous bed, the great irregularities and the softness of the enclosing strata do not permit the presentation of conclusive proofs.

The most striking evidence of continuity with which the writer is familiar is the result of a great many bore-holes, extending over a distance of about 6 miles. These holes were located with special reference to intersecting the strata at points where they had not been disturbed; and in all cases the bed of ore, having approximately the same character and underlain by uniformly similar material, was found a short distance above the Potsdam sandstone.

The average of a series of analyses made by Dr. McCreath from his own sampling gives to these ores:

	Per cent.
Iron,	48.646
Phosphorus,	0.259

These samples were taken from the surface-workings. As a rule, the ores have been found to improve somewhat in quality, and to become more massive, at a short distance below the surface.

At times the ores become highly manganiferous. Deposits of high-grade manganese are also found in this formation, and are at times closely associated with the iron-ore. In some places the manganese-ore seems to exclude the iron-ore.

The very great extent of territory over which these ores are found, and the fact that they are at certain points developed by extensive workings, give abundant evidence as to the very large amount of them which may in time become available. The irregularities above referred to must, however, be borne in mind, as well as the difficulties which may at times attend prospecting

work, but do not detract from the very large amount of ore which will ultimately be derived from these measures.

The following data concerning various questions pertinent to the value of the Potsdam ores have been grouped under appropriate headings:

Percentage of Iron in the Ore as now Mined.—There are few mines of any extent based upon these ores from Roanoke northward. The works of the old charcoal-iron makers are found extending throughout this district. They only used the best ore, as the amount required was small. Such ore was always of high metallic contents. Information has been given already as to the result of numerous samples selected along this belt by McCreath, and analyzed by him.

The comparatively small development which has taken place since the advent of rail-transportation in 1882 may be represented to-day by three or four mines near Roanoke; the Mine bank, Black Rock mine and Mary Creek mine near Vesuvius, Va., the mines of the Buena Vista Company, at Buena Vista, and the Shenandoah Furnace Company's mines. There are numerous smaller operations, started by farmers and local owners without capital or equipment, and discontinued whenever the demand for ore falls off.

The most celebrated operations near Roanoke are the Rorer mines, just south of the city; the Upton mines of the Crozer Company, about 12 miles east of the city; and mines adjoining these, known as the Lynchburg mines.

The Crozer mines consist entirely of two open cuts of great magnitude, in which the indication of the displaced and broken division of the vein is very apparent. While there is a great deal of good ore, much of it is lean and there is a very large amount of dead material handled, which, necessarily, more or less contaminates the ore.

One of the mines near Roanoke averages 42 per cent. iron; another, 45 per cent. The general opinion of those using the ores from the mines near Roanoke is, that as mined and handled, they will not average over 42 or 43 per cent.

The Mine bank, which discontinued shipment on account of the excessive proportion of manganese in the ore, furnished an ore well up in metallic contents, approaching, as I am credibly informed, about 50 per cent. This mine is located at one end

of a peculiar little basin, from which everything has been eroded down to the ore-bearing shales. At the Mine bank the ore shows a thickness across the bedding of about 50 feet, and can be traced by very heavy outcrops and openings for a distance of 1½ miles beyond the boundary of the Mine bank property through what is known as the St. Mary's iron lands.

Considerable shipments from the Mine bank ran less than 0.08 per cent. in phosphorus, and most of it ran quite high in manganese; at times being really a manganese-ore. In both of these ingredients the ore, as a whole, is irregular, and this is true of the entire basin. But if a market can be found for ore of variable phosphorus and manganese contents, this basin could, by selection, furnish a large quantity of ore high in manganese and low in phosphorus. The total amount of ore to be found in this basin is undoubtedly very large.

The mines at Buena Vista were unsuccessful, being, from the best information at my disposal, in the drift or misplaced portion of the deposit. No reliable information is at hand as to the percentage of iron in the ore.

The chemist of one of the other mines above named tells me that their ore, as mined and furnished to the furnace, did not average over 41 per cent. iron. The ore of another mine is reported at about 40 and that of still another at about 42 per cent.

However good may be the indications, therefore, I do not think it safe to assume that the ores of these measures *in large quantities*, and under the ordinary method of mining and washing, will run higher in iron than between 42 and 43 per cent.

Percentage of Iron Which Could be Secured with More Care in Mining.—The chemists at all the furnaces and mines agree that these ores could be improved by better picking, by jigging, and by excluding well-recognized lean ore, which, under present conditions of operating, the miner cannot afford to throw away. This opinion was confirmed by my own observation. But it is exceedingly difficult to say how much the ore could be improved; and I think it wisest not to assume that the natural ore at any point will be better than at the few points where it is at present developed and worked; although, in the large territory covered, it is quite possible that this may prove to be the case.

At one furnace some jig-tests were made. Three car-loads of fine material, which they told me represented about one-half of their output, and which carried 38 per cent. of iron (the other half carrying over 44 per cent.) were treated through. There was a loss of one-third of the jigged material, and the concentrates carried 46 per cent. In other words, by a loss of one-sixth of the total ore mined, or, say, an addition of one-fifth to the cost of the product, the whole output could be changed from a 41 to a 45 per cent. ore. The ore had been imperfectly sized, and better results could have been got by crushing and sizing. From the general information at my disposal, I believe it will be possible to concentrate these ores to 45 or 46 per cent. It may be possible to do better; but I do not think it wise in the present state of our knowledge to assume that such would be the case. I do not believe it would be commercially practicable to obtain, in large quantities, ore carrying 50 per cent. of iron.

Condition of the Silica in the Ore.—The silica occurs almost entirely combined, in silicates representing all grades from pure clay up to a clayey iron-ore.

The following full analysis of a sample from the Mt. Vernon property may prove of interest in this connection; the sampling and analysis were done by the United States Census of 1880. Other analyses at my disposal show a large per cent. of silicate of alumina:

Raines and Weaver Banks Mixed Lump-Ore.

	Natural Ore. Per cent.	Dried Ore. Per cent.
Silica,	9.68	9.75
Iron peroxide,	73.28	73.78
Alumina,	2.43	2.45
Manganese, protoxide,	0.15	0.15
Manganese, dioxide,	2.84	2.86
Lime,	0.07	0.07
Magnesia,	0.22	0.22
Iron, disulphide,	0.008	0.008
Nickel, oxide,	0.14	0.14
Carbonic acid,	0.07	0.07
Phosphoric acid,	0.237	0.239
Titanic acid,	Trace.	Trace.
Carbon in carbonaceous matter,	0.15	0.15
Hygroscopic water,	0.67	——
Water of composition,	9.89	9.95
Total,	99.835	99.837

	Natural Ore. Per cent.	Dried Ore. Per cent.
Sulphur,	0.004	0.004
Phosphorus,	0.103	0.104
Metallic iron,	51.30	51.65

Insoluble siliceous matter:

	Per cent.	Per cent.
Silica,	9.68	9.75
Alumina (with trace of iron),	1.38	1.39
Lime,	0.07	0.07
Magnesia,	0.10	0.10
Phosphoric acid,	0.020	0.020
Titanic acid,	Trace.	Trace.
Total insoluble matter,	11.25	11.33

This percentage of siliceous matter I believe could be reduced in the manner and to the extent referred to above in connection with the question of concentration.

Amount of Phosphorus in the Ore.—The phosphorus in the ores near Roanoke runs high, varying from 0.60 to 0.90 per cent. In the mines farther north the amount seems to be very much less. The ore from the mines near Vesuvius varies as a whole between 0.20 and 0.40 per cent., but considerable quantities of ore can often be found quite low in phosphorus. The manager of the Shenandoah Iron Works reports that the phosphorus in their ore varies between 0.20 and 0.25 per cent.

Cost of Mining.—As is evident from the information given as to the occurrence of these ores, the cost of mining must vary greatly from time to time. At times large masses of ore are encountered which can be mined with great cheapness, while at other times the occurrence of irregularities and the necessity for moving large amounts of dead material rapidly increase the cost. I do not consider it wise, therefore, to assume that the cost can be materially reduced below the figures obtaining at the mines above referred to. The following facts will prove of interest in this connection:

At one mine near Roanoke about 180 to 200 tons per day are mined with about 100 men, all told. The water for washing is pumped three-fourths of a mile. This ore has been sold at prices ranging from $1.20 to $1.40 per ton delivered at the yards at Roanoke.

At another mine 120 men, all told, get out 200 tons of ore

per day. There are two locomotives, and the larger portion of the water used for washing is pumped from a well. The irregularities of the water-supply have contributed largely to irregularities in working, and must have increased the cost.

At another mine the lessees are of the opinion that they will be able to get out 100 tons daily with 40 men.

At another mine, which is doing a good deal of stripping, 150 men are getting out 120 tons daily.

At all these places the wages are 75 cents per day for open-cut work and 85 cents for tunnel-work.

At the mines near Vesuvius ore was produced at a total cost of about 90 cents per ton, including the rental of equipment and the royalty charged.

Considering all these facts, I think $1 per ton of concentrated ore is a safe estimate of cost when operating with sufficient capital to permit of economic work. I do not think it safe to assume that this cost can be reduced, though perhaps a reduction is possible.

Capacity of the Deposits.—As I am informed, the largest amount ever taken from a single one of these operations was about 400 tons per day. Apparently the irregularities from point to point have prevented arrangements at any single mine for handling a very large output.

As it often happens that a single local thickening or well-developed occurrence of the ore (colloquially known as a "Bank") can be exploited very cheaply, it is conceivable that the aggregate of a number of such works might amount to a large daily output. I believe such would be the case. At times these deposits swell out to a thickness of 50 to 100 feet or more.

With regard to their total capacity, it may be observed that the two open cuts of the Crozer mines have yielded between 600,000 and 700,000 tons of ore; and it is believed that about the same amount has been produced from the Fox Mountain mine of the Shenandoah Furnace Co.

Character of Work Done in Washing.—In these ores the impurity consists often of a tough clay, requiring a good deal of water, and making it difficult to wash the ore thoroughly. This, and the fact that water is often scarce, makes the washing often inadequate. There could be, therefore, a decided improvement in this respect.

Amount of Ore and Coke Required to Make a Ton of Iron.—Owing to the fact that these ores, as developed near Roanoke, carry a good deal more manganese and something more of phosphorus than is desired, all the furnaces use other ores as "mixers." It is impossible, therefore, to answer this question satisfactorily as to the ore. As regards the consumption of coke, the furnace-men all agree that this ore reduces with remarkable readiness almost as soon as it enters the top of the furnace. At the same time the coke-consumption is not remarkably low. There are no furnaces working entirely on ores from these measures. Consumption on mixed ores with furnace burdened for mill-iron, and ore averaging 49 per cent., has been reported as low as 2020 pounds coke to 2260 pounds iron. From another furnace it is reported that with mixture running from 41 to 42 per cent. of iron, and burdened for foundry-iron, the coke-consumption was 2700 pounds per ton of iron.

The coke used is Pocahontas. It varies considerably; but the following would be an average sample, probably of the better quality:

Fixed carbon,	91.77
Volatile matter and water,	1.07
Sulphur,	.56
Ash,	6.60

The coke of the district, as a whole, cannot be considered as well-made. It varies very greatly in physical properties. It is often of small size, and the occurrence of black ends and soft material, in quantity, is by no means uncommon. The coal is sold principally as a steam-coal, and coke-making has not received the best attention of the operators.

Methods of Mining.—The methods used are in many cases peculiarly well adapted to the prevailing conditions. Steam-shovels have never been used. Certainly at some points, owing to the soft and friable nature of the enclosing material, they could be used to advantage. They represent the only form of improvement which could be introduced with probability of success.

Important Results Obtained in the Past Fifteen Years with the Stiff and Heavy Rail-Sections.

BY P. H. DUDLEY, NEW YORK CITY.

(New York Meeting, February, 1899.)

WHEN we see the magnificent passenger-trains of from 8 to 12 coaches, drawn by locomotives weighing from 100 to 110 tons, at speeds of from 50 to 60 miles per hour between terminals, to make a schedule of 45 miles per hour, and freight-trains of from 50 to 75 cars of 60,000 pounds capacity, drawn by one locomotive, it is hard to realize that it lacks a few months of fifteen years since my pioneer 5-inch 80-pound rail for the United States was laid by the New York Central and Hudson River Railroad Co., in July, 1884, on the Harlem line.

Shorter passenger-trains, of from 4 to 5 coaches, are run much faster, notably the Empire State Express, the schedule of which for the 440 miles between New York and Buffalo requires 53.3 miles per hour, calling for a running-speed, for much of the time, of from 65 to 75 miles per hour, while higher speeds are very common.

On other railroads laid with my 5⅛-inch 80-pound rail, speeds of from 60 to 75 miles per hour obtain in daily practice.

On many of the important railroads east of the Mississippi high speeds of from 60 to 70 miles per hour are part of the daily service.

So many instances of speeds of 90, and even 100, miles per hour have been recorded that they must be considered as likely to occur on important lines, and provision must be made for them in the track.

Solid mail-trains of from 6 to 8 cars are run from New York to Chicago, 1000 miles, in twenty-four hours; and, commencing with the present year, shorter trains are running from Chicago to San Francisco, 2000 miles, in three and one-half days.

In the freight-service equally important progress has been

made. Within the past fifteen years the 20,000-pound capacity cars, with about same dead load for the structure, have been replaced with cars of 60,000-pound capacity, the weight of which is about 45 per cent. of the capacity-weight. Experience has been so satisfactory with the 60,000-pound cars that cars of 80,000-pound capacity have been constructed, and many are in service. Many railroad companies, believing that the capacity of the cars should be farther increased, are constructing 100,000-pound cars (dead load about 39 per cent. of the capacity), and many thousands of such cars are now running, to meet commercial competition and save something out of the prevailing low rates for freight.

There seems to be no prospect of a decrease in static wheel-loads and in the speed of trains. On the contrary, both are increasing, and the severer requirements of service must be met largely by applying principles now well known to prevent the generation of large destructive dynamic forces under the moving trains, and by raising to a higher efficiency, in an economical way, everything which appertains to transportation.

The loads under moving trains, which the rails and road-bed must sustain, are the combined effects of the static wheel-loads and the generated dynamic effects, the latter often excelling the former.

One of the great advantages of the recent stiff rails, as factors in the higher standard of track obtained, has been not only to check the generation of so large destructive dynamic effects from the static loads, as was the case on the lighter rails, but, after that, to distribute the reduced load over larger areas of the road-bed.

In other words, the heavier static loads with the lessening dynamic loads are not so destructive to the ties and road-bed on the stiff rails as was the case with lighter static but greater dynamic loads on the weak rails.

This important fact is proved conclusively by the higher standards of track attained on the heavy rails, though under a greater volume of traffic.

Brief mention of the investigations of the condition of the track and forms of permanent set, found in the lighter rails in the track, which preceded and led to the design of my pioneer

5-inch 80-pound section has been made in former papers* and need not be repeated here.

In 1883, after I had designed my pioneer 80-pound section, and before any rails of that design had been rolled, I made some deductions, from the study of the many diagrams of track I had taken with my apparatus on 4- and 4½-inch rails, as to the possible results which could be expected from labor and from material, respectively, in reducing the undulations in the track, as summed up by the mechanism of my car. I used these results to calculate what could be expected on smooth 5-inch rails, making the calculation specially for the Boston and Albany Railroad, and put it on their condensed diagrams, indicating that by the use of stiff 5-inch smooth rails, good ballast and skilled labor, they could reduce the average undulation per mile for the entire road, so that it would fall between the fifteenth and sixteenth line on the condensed diagrams.

To the railroad officials, and especially to the Department of the Maintenance of Way, this seemed at that time an impossibility; for it meant a reduction of two-thirds of the amount of the undulations per mile in the track.

The condition of the track, so difficult to maintain at a high standard on the mountain slopes, gave little promise to them that so great a reduction could be made.

It was true that the condition of the track on the 4½-inch 72-pound rail was somewhat better than on the 4-inch 63-pound rail, but not sufficient to indicate to them that a 5-inch rail with a broad head would make a track 60 per cent. better than the 4½-inch 72-pound rail.

In 1884 my pioneer 5-inch 80-pound rail was rolled and straightened at the mill on the same presses, having narrow-spaced anvil-blocks, used for lighter rails. The required blows to straighten the rails were too severe, the gag producing indentations in the metal of the rail-heads, besides often producing short bends in the rails. The surface of the rails was wavy, and could not be improved by labor on the track; therefore the undulations were not reduced to as low figures per mile as I had calculated. Repeated inspection of the tracks with my car indicated that the principal cause was due to dif-

* *Trans.*, xvii., 783 to 784, and xviii., 228 to 242, and 763 to 798.

ficulties in straightening the rails which could be largely overcome.

The mechanical element of stiffness in a steel rail-section for a given weight of metal is due more to the design and distribution of the metal than to its physical properties.

To lessen the deflections in the tracks under the wheel-loads, stiffness was a primary consideration in my design of the 80-pound section. The head was made broad for the increased wheel-pressures, for wear, and in order to increase largely the side-stability of the rails in the track, and prevent both lines of rails from rolling out and widening the gauge, and increasing the wear of the rails on curves.

It required proof in the track to convince many of the correctness of the simplest of the theoretical, or, I may almost say, practical considerations.

The 5-inch 80-pound rail demonstrated in the track to a great many railway officials and others, by its lessened deflection, the value of the mechanical element of stiffness of a rail-section in maintenance of way; and 5-inch 80-pound rails, or those of greater weight, became common for renewals on eastern lines.

Colonel Prout in writing of my 5-inch 80-pound section, in the *Engineering Magazine* of July, 1897, says: "It marked an epoch in rail-sections."

As an educator in demonstrating the principle of increased stiffness per weight in a rail-section for carrying greater loads, and for ease of maintenance, it hastened the work of strengthening the permanent way of our railroads, putting them upon a better physical basis for their traffic than had existed previous to its introduction, regardless of the amount of labor expended in maintenance of way on the lighter and weaker sections.

The undulations in the track were reduced practically one-half by the 5-inch rails, compared to the 4½-inch rails.

The splice-bars could be made stiff enough so that the joints of the 5-inch rails could be maintained in surface without excessive labor. The stability of the track was largely increased, with much less cost of maintenance.

The mechanical element of increased stiffness in the 5-inch and higher rail-sections was ever present to lessen the effects of

every passing wheel-load on the ties and road-bed, by distributing them over a greater longitudinal area, thus benefiting particularly the road-bed.

To this important fact much of the success of the stiff rails is due.

In 1890, the Boston and Albany Railroad Company proposed to change from their 4½-inch 72-pound section, which they had adopted in 1880, to a 5-inch 95-pound rail.

From the large amount of work constantly required to "adze" the ties, and "roll in" the 4- and 4½-inch rails on the curves (the track rarely being in gauge on the curves combined with heavy gradients), they were apprehensive that any section higher than 5 inches would so largely increase the tendency to "roll" as not to be permissible. I distributed the metal in the head, making it broad, to secure greater vertical and lateral stability, and to reduce the uneven surface-wear incidental to narrow-topped rails on gradients and curves. The base of the rail was made 5½ inches wide.

I wished to make the rail higher, and have the benefit of greater stiffness; and I also proposed that the rails should be rolled out of a high grade of tough steel of high elastic limit, so that the rails would wear well, and not take a set in the track, until the extreme fibers were stressed over 55,000 to 60,000 pounds per square inch.

A long discussion followed this proposition. From my investigations of many years, I was firmly convinced that such rails could be made which would be tough, quite hard and yet not brittle. Mr. John Fritz confirmed this opinion.

Mr. William Bliss, President of the Boston and Albany Railroad Company, was willing to meet the manufacturers in a fair spirit in contracting for such rails, and, in fact, paid the Bethlehem Iron Company $2 per ton over the market-price for ordinary rails. Of this type, 11,000 tons were rolled and laid in 1891, and 6000 tons more in 1892.

I personally went to the mill, and had the anvils on the straightening-presses lengthened, and the anvil-blocks set 44 inches apart, so that lighter blows would straighten the rails without indenting of the heads by the gags.

After a short experience, the men were able to straighten the rails so that they could be finished very smooth.

In 1891 Dr. W. Seward Webb commenced to build the Mohawk and Malone Railway and used my 5-inch 75-pound broad-top section, to the extent of some 30,000 tons of rails. These were laid, in most cases, before the road could be ballasted, but their stiffness protected them from injury from that cause.

In the tracks, the 95-pound rails of the Boston and Albany Railroad showed a marked reduction in undulations per mile, the figures in the first season being nearly down to my calculations of 1883. It requires two years, and something more, before heavy rails reach their highest condition in the track.

In 1892, the New York Central and Hudson River Railroad Company laid my 6-inch 100-pound section, the first 100-pound section rolled in this country. Now there are many hundreds of miles of 100-pound rails in the tracks of our eastern railroads.

In 1893, the Boston and Albany 95-pound rails were rolled by the Lackawanna Iron and Steel Company at the same price as ordinary rails. The low prices for steel hastened the relaying with 95-pound rails of the entire line of this road, which was completed in 1897.

In 1897, the average undulations in the track per mile for the entire road, as summed up by my car, were equivalent to 15.42 lines on the condensed diagrams, confirming my calculations of 1883. It should be said that the railroad company did all that was possible to keep and maintain the condition of the track up to the full value of the rail-section. To secure such a result, the condition of the track over the mountains must be practically as good as on the level portions of the line. The smoothness and consequent smooth wearing-properties of the 95-pound rails have been so largely increased over those of the former 63- and 72-pound rails on the heavy gradients as to render possible this important result, even after six years' service on many of the rails.

The inspection for 1898, the first year of maintenance of the whole line with the new rail-section, shows a still better result; the average undulation per mile for the entire road being reduced to 14.2 lines on the condensed diagrams, practically securing the full value of the 95-pound section.

I copy a few paragraphs from the sheets of the condensed diagrams of the Boston and Albany Railroad.

"The result is as remarkable as it is gratifying, and is unique in the development and maintenance of a high standard of track on a mountainous line; for the general experience has been that it has not been possible to maintain nearly as good a 'condition of track' over the heavy gradients as on the more level portions of the line.

"Before the use of broad-topped rails, the universal fact in all countries of steel rails wearing more uneven and faster on the heavy gradients than on the other portions of the line under the same tonnage has led to the general opinion that the 'condition of track' must be expected to become much worse on the gradients and a limiting factor for the trains' loads.

"Such an opinion was expressed by several Continental engineers at the International Railway Congress held in London in 1895."

The important results secured on the Boston and Albany Railroad show that by the form of section and grade of steel we have materially checked the rate of irregular wear on the combined gradients and curves of the line, so that not only is the condition of the track very uniform per mile for the entire road, but also the full value of the rail-section has been obtained and maintained on the heavy gradients.

This evidence is confirmed by the results obtained in six years' service from broad-topped 75-pound rails on the Mohawk and Malone Railroad, over the mountains.

On the Adirondack and St. Lawrence line from Malone my 75-pound section is laid to the Canadian line, and is there joined by Sandberg's 5-inch round-top 72-pound rail. The undulations on the latter are more than double those on the 75-pound rail for the same traffic.

On the Cincinnati Southern Railway, using broad-topped 75-pound rails, the condition of track over the mountains in Tennessee is quite as good as on the more level portions of the line.

On the stiff rails, made of the higher carbon-grades of steel, the joints can be and are easily maintained, the rails keeping in good surface without permanent set, and their receiving-ends remaining unworn, in striking contrast to the opposite conditions formerly exhibited on the lighter rails.

Another important feature of the broad-topped stiff rails, as designed, is that the wheel-loads, acting through the treads of the passing wheels, are made to do duty in holding the rails in their normal position in the track, checking the tendency to "roll," widen the gauge and spread on the curves. Moreover, the cutting out of the ties under the rails has been very much reduced by the use of such rails.

The broad-topped rails do not require bracing on curves of 4° and larger radii, even for speeds exceeding 60 miles per hour.

On the heavy gradients of the Boston and Albany Railroad the curves are not braced, yet remain in gauge; and not a single curve has been "rolled in" on the 95-pound rails since they were laid. Only actual experience has convinced the track-men that such results were possible.

The ties on all curves of the Boston and Albany Railroad are provided with tie-plates; but even on other railroads, not using such plates, it has not been necessary, in using these rails, to "adze" the ties and "roll in" the rails in order to maintain the gauge. This is a very important matter for the stability of the track, besides contributing to the longer life and better service of the ties.

Again, the life of the wheel-tires has been very much increased by the use of such rails, there having been a gain amounting to 40 and 50 per cent. in the practicable mileage between successive turnings of steel tires.

Twenty-three years ago* I reported to the Institute that I found the resistance per ton of freight-trains of 25 to 30 cars (gross load 600 to 700 tons) to be 6 to 8 pounds per ton on light steel rails, at speeds of 18 to 20 miles per hour. To-day, on my 5⅛-inch 80-pound rails, for a train of 81 cars of 60,000 pounds capacity, making a total load of 3428 gross tons, the resistance shown by indicator-cards, for a speed of 20 miles per hour, is only some 3 pounds per ton for the level portions of the line.

The energy required to be stored in such a train before it can attain the speed of 20 miles is equivalent to 92,000,000 foot-pounds, which the locomotive must generate on a level line, besides overcoming the ordinary resistance to the train. In the case just cited, the locomotive was worked nearly at a constant effort, developing from 700 to 750 horse-power; the train giving out energy on the ascending-gradients and storing up energy on the descending-gradients.

On one light descending-gradient of some length, the train attained a speed of 30 miles per hour, the stored energy being equivalent to 205,000,000 foot-pounds.

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* *Trans.*, iv., 232, "Railway Resistances."

The ability to generate and control such great forces emphasizes the progress achieved during the past few years in every department of railway engineering.

This advance brings daily new problems for solution. There is still much to be done to raise to higher efficiency the practical applications of established principles, so as to meet the increased severity of service which improved conditions have rendered possible.

The problem, or rather series of problems, in regard to the stresses in rails, is so complex that no one has as yet been able to make a mathematical analysis of them which satisfies the conditions of practice. These stresses can only be determined experimentally in the track.

That the stresses in rails have always been large is well known. *The fact that they are of short duration permits stresses in them which would not be permissible in bridges.* The set in rails, described in my former papers, shows that the light rails were frequently subjected to stresses beyond the elastic limit of the steel.

The recent experimental work with my Stremmatograph in determining the stresses in rails under moving trains establishes the important fact that the metal in rails is subjected to very large fiber-stresses, and shows how these stresses are distributed in heavy rails. Some of these results have been published. I append tabulations of such work, the significance of which engineers will readily understand.

For this purpose, I have taken the records of two tests, made on the New York Central and Hudson River Railroad, at the same point and on the same day, and within a few minutes of each other, the one being taken under the Empire State Express, leaving the Grand Central station at 8.30 A.M., and the other under the Adirondack and Montreal Express, leaving the same station three minutes later, and both passing the point where the records here tabulated were taken at the same speed, and under the same conditions as to temperature in the rail-head. It will be seen that variations due to speed, temperature and condition of track have thus been eliminated, but that those due to weight of engines and cars, and condition of wheel-tires, remain.

New York Central and Hudson River Railroad, June 28, 1898.

Rail: 6-*inch*, 100-*pound, outside, on* 3-*degree curve above* 49*th St., N. Y. City.*
Train: No. 51, *Empire State Express, leaving Grand Central Station at* 8.30 *A.M.*
Locomotive: No. 870; *weight*, 202,000 *pounds.*
Cars: Combination baggage and smoker, No. 424, weight, 95,000 pounds; vestibule coaches: No. 936, weight, 86,000 pounds; No. 914, weight, 82,000 pounds; Wagner coach, No. 118, weight, 94,950 pounds.
Speed: 19 *miles per hour.*
Temperature in Rail-head: 90° Fahr.

Empire State Express.

The apparent mean extreme fiber-stresses per square inch in five inches of the length of the base of the rail were as follows:

			Pounds.		
Locomotive	Engine	Compression in front of truck wheel	2,362		
	Engine – Truck	Tension under front truck wheel	13,227		
	Engine – Truck	Compression between front and rear truck wheel	6,850		
	Engine – Truck	Tension under rear truck wheel	7,086		
	Engine	Compression between rear truck wheel and front driver	5,669	59,665	
	Engine – Drivers	Tension under front driver	8,267		
	Engine – Drivers	Compression between front and rear driver	7,086		
	Engine – Drivers	Tension under rear driver	6,141		
		Compression between rear driver and front tender wheel	5,669		97,768
	Tender – F. T.	Tension under front tender wheel	4,960		
	Tender – F. T.	Compression between front truck wheels	2,884		
	Tender – F. T.	Tension under rear tender wheel front truck	5,905		
	Tender	Compression between front and rear truck	5,432	38,108	
	Tender – R. T.	Tension under front tender wheel rear truck	4,448		
	Tender – R. T.	Compression between front and rear wheels	3,307		
	Tender – R. T.	Tension under rear tender wheel	6,377		
		Compression between rear tender wheel and car wheel	4,015		
Train	First Car – Front Truck	Tension under front car wheel	7,086		
	First Car – Front Truck	Compression between front and middle wheel	3,307		
	First Car – Front Truck	Tension under middle wheel	5,905		
	First Car – Front Truck	Compression between middle and rear wheel	3,543	32,006	
	First Car – Front Truck	Tension under rear truck wheel	7,795		
	First Car	Compression in rear of wheel	2,362		
	First Car	Compression in center of space between trucks	472		65,310
	First Car	Compression in front of first truck wheel	445		
	First Car – Rear Truck	Tension under front wheel	11,574		
	First Car – Rear Truck	Compression between front and middle wheels	3,307		
	First Car – Rear Truck	Tension under middle wheel	5,196	33,304	
	First Car – Rear Truck	Compression between middle and rear wheels	2,598		
	First Car – Rear Truck	Tension under rear wheel	8,503		
		Compression between trucks of first and second cars	2,362		
	Second Car – Front Truck	Tension under front wheel of truck of second car	6,614		
	Second Car – Front Truck	Compression between front and middle wheel	3,307		
	Second Car – Front Truck	Tension under middle wheel	2,834		
	Second Car – Front Truck	Compression between middle and rear wheel	2,834	23,383	
	Second Car – Front Truck	Tension under rear wheel	5,432		
	Second Car	Compression in rear of wheel	709		
	Second Car	Compression in center of space between trucks	472		46,546
	Second Car	Compression in front of wheel of rear truck	1,890		
	Second Car – Rear Truck	Tension under front wheel	8,976		
	Second Car – Rear Truck	Compression between front and middle wheel	4,015	23,163	
	Second Car – Rear Truck	Tension under middle wheel	4,724		
	Second Car – Rear Truck	Compression between middle and rear wheel	2,362		
	Second Car – Rear Truck	Tension under rear wheel	3,779		

Empire State Express.—Continued.

Train			Pounds.		
		Compression between rear truck of second car and front truck of third car	2,834		
Third Car	Front Truck	o Tension under front wheel of third car	5,196		
		Compression between front and middle wheel	472		
		o Tension under middle wheel	3,307		
		Compression between middle and rear wheel	1,181	19,120	
		o Tension under rear wheel	5,432		
		Compression in rear of wheel	1,643		
		Compression in center of space between trucks—shocks	472		45,930
		Compression in front of wheel of rear truck	709		
	Rear Truck	o Tension under front wheel of rear truck	10,629		
		Compression between front and middle wheels	1,890		
		o Tension under middle wheel	1,890	26,810	
		Compression between middle and rear wheels	2,362		
		o Tension under rear wheel	8,267		
		Compression between rear wheel of third car and front wheel of fourth car	2,126		
Fourth Car	Front Truck	o Tension under front wheel of fourth car	7,322		
		Compression between front and middle wheel	3,071		
		o Tension under middle wheel	3,543		
		Compression between middle and rear wheel	3,071	23,976	
		o Tension under rear wheel	4,017		
		Compression in rear of wheel	1,417		
		Compression in center of space between trucks	472		
		Compression in front of truck wheel	945		53,738
	Rear Truck	o Tension under front wheel	9,684		
		Compression between front and middle wheel	1,890		
		o Tension under middle wheel	7,795	29,762	
		Compression between middle and rear wheel	2,834		
		o Tension under rear wheel	5,905		
		Compression in rear of wheel	709		
		Instrument returned to Zero after passage of train.			

NOTE.—It will be observed in this and the following tables, that in the second column of figures under "Pounds," the aggregates given are not the exact totals of the figures covered by the adjacent brackets. This is due to a division of stresses noted between trucks, or between engine and tender—part of each such stress being charged to one head, and the remainder to the other. This distribution is sometimes arbitrary, half to each; but it is sometimes affected by indications of the apparatus, showing to which truck the stress should be charged.

New York Central and Hudson River Railroad, June 28, 1898.

Rail: 6-*inch*, 100-*pound, outside, on* 3-*degree curve above* 49*th St., N. Y. City.*
Train: No. 57, *Adirondack and Montreal Express, leaving Grand Central Station at* 8.33 *A.M.*
Locomotive: No. 885; *weight,* 200,000 *pounds.*
Cars: Baggage, No. 1912, *weight,* 53,650 *pounds; Smoker, No.* 2344, *weight,* 51,900 *pounds; vestibule coach, No.* 938, *weight,* 81,400 *pounds; Wagner coaches: No.* 133, *weight,* 96,300 *pounds; No.* 68, *weight,* 103,200 *pounds; No.* 123, *weight,* 95,500 *pounds.*
Speed: 19 *miles per hour.*
Temperature in Rail-head: 90° Fahr.

Adirondack Express.

The apparent mean extreme fiber-stresses per square inch in five inches of the length of the base of the rail were as follows:

				Pounds.		
LOCOMOTIVE	ENGINE		Compression in front of truck wheel	3,807		
		Truck	o Tension under front truck wheel	10,865		
		Truck	Compression between front and rear truck wheel	6,877		
		Truck	o Tension under rear truck wheel	6,377		
			Compression between truck wheel and front driver	5,905	58,459	
		Drivers	⊙ Tension under front driver	4,960		
		Drivers	Compression between drivers	8,031		
		Drivers	⊙ Tension under rear driver	9,448		
			Compression between rear driver and front wheel of tender	6,877		95,898
	TENDER	F. T.	o Tension under front tender wheel	3,071		
		F. T.	Compression between tender wheel and front truck	3,779		
		F. T.	o Tension under rear tender wheel front truck	4,488		
			Compression between front and rear tender truck	5,669	37,439	
		R. T.	o Tension under front tender wheel rear truck	4,489		
		R. T.	Compression between wheels of rear tender truck	3,543		
		R. T.	o Tension under rear tender wheel	7,086		
			Compression between tender wheel and front car wheel	4,253		
TRAIN	FIRST CAR	F. T.	o Tension under front wheel of car truck	6,377		
		F. T.	Compression between front and rear wheels of truck	3,071	18,896	
		F. T.	o Tension under rear wheel of truck	5,669		
			Compression back of wheel	1,653		
			Compression in center of space between trucks—shocks	1,890		34,479
			Compression in front of wheel of rear truck	2,472		
		R. T.	o Tension under front wheel of truck	4,253		
		R. T.	Compression between front and rear wheel	3,071	15,583	
		R. T.	o Tension under rear wheel of truck	3,071		
			Compression between trucks of first and second cars	1,653		
	SECOND CAR	F. T.	o Tension under front wheel of second car	6,850		
		F. T.	Compression between front and rear wheel	2,125		
		F. T.	o Tension under rear wheel of truck	3,779	16,178	
			Compression back of wheel	1,890		
			Compression in center of space between trucks	708		35,193
			Compression in front of wheel of rear truck	1,181		
		R. T.	o Tension under front wheel of rear truck	8,976		
		R. T.	Compression between front and rear wheel	2,598	19,015	
		R. T.	o Tension under rear wheel	4,488		
			Compression between trucks of second and third cars	3,543		

Adirondack Express.—Continued.

Train	Car	Truck		Pounds.		
TRAIN	THIRD CAR	Front Truck	Tension under front wheel of third car	6,614		
			Compression between first and middle wheel	1,890		
			Tension under middle wheel	5,196		
			Compression between middle and rear wheel	2,834	25,155	
			Tension under rear wheel	4,960		
			Compression back of wheel	1,653		
			Compression in center of wheel space	236		49,721
			Compression in front of wheel of rear truck	1,417		
		Rear Truck	Tension under front wheel of rear truck	7,322		
			Compression between front and middle wheels	2,126		
			Tension under middle wheel	4,253		
			Compression between middle and rear wheel	3,307	24,566	
			Tension under rear wheel	4,488		
			Compression between rear wheel of third car and front wheel of fourth car	3,307		
	FOURTH CAR	Front Truck	Tension under front wheel of fourth car	4,015		
			Compression between front and middle wheel	4,015		
			Tension under middle wheel	2,126		
			Compression between middle and rear wheel	3,543	23,383	
			Tension under rear wheel	5,905		
			Compression in rear of wheel—shocks	2,126		
			Compression in center of space between trucks			
			Compression in front of truck wheel	1,653		54,325
		Rear Truck	Tension under front wheel	6,850		
			Compression between front and middle wheel	6,141		
			Tension under middle wheel	3,543		
			Compression between middle and rear wheel	4,724	30,942	
			Tension under rear wheel	5,905		
			Compression between rear wheel of fourth and front wheel of fifth car	4,253		
	FIFTH CAR	Front Truck	Tension under front wheel of fifth car	7,795		
			Compression between front and middle wheel	4,253		
			Tension under middle wheel	6,141		
			Compression between middle and rear wheel	4,015		
			Tension under rear wheel	8,503	36,611	
			Compression in rear of wheel	3,778		
			Compression in center of space	0		
			Compression in front of wheel	3,543		75,111
		Rear Truck	Tension under front wheel	11,574		
			Compression between front and middle wheel	4,015		
			Tension under middle wheel	6,614		
			Compression between middle and rear wheel	4,015	38,500	
			Tension under rear wheel	7,558		
			Compression between rear wheel of fifth and front wheel of sixth car	2,362		
	SIXTH CAR	Front Truck	Tension under front wheel	7,322		
			Compression between front and middle wheel	3,867		
			Tension under middle wheel	3,307		
			Compression between middle and rear wheel	3,307	26,927	
			Tension under rear wheel	5,669		
			Compression back of wheel	2,834		
			Compression in center of space between trucks	0		
			Compression in front of front wheel of rear truck	3,543		61,885
		Rear Truck	Tension under front wheel of rear truck of sixth car	7,086		
			Compression between front and middle wheel	6,141		
			Tension under middle wheel	4,253		
			Compression between middle and rear wheel	5,432	34,958	
			Tension under rear wheel	4,724		
			Compression back of wheel	3,307		
			Shocks	472		

Instrument returned to Zero after passage of train.

New York Central and Hudson River Railroad, July 21, 1898.

Ties slightly tamped near stremmatograph.

Rail: 6-inch, 100-pound, outside, on 3-degree curve above 49th St., N. Y. City.

Train: No. 51, *Empire State Express, leaving Grand Central Station at* 8.30 *A.M.*

Locomotive: No. 870 ; *weight,* 202,000 *pounds.*

Cars: Combination baggage and smoker, No. 424, weight, 95,000 pounds; vestibule coaches: No. 936, weight, 86,000 pounds; No. 914, weight, 82,000 pounds; Wagner coach, No. 118, weight, 94,950 pounds.

Speed: 19 *miles per hour.*

Temperature in Rail-head: 110° Fahr.

Empire State Express.

The apparent mean extreme fiber-stresses per square inch in five inches of the length of the base of the rail were as follows:

			Pounds.		
Locomotive	Engine	Compression in front of truck wheel	2,598		
	Truck	Tension under front truck wheel	13,699		
	Truck	Compression between front and rear truck wheel	4,488		
	Truck	Tension under rear truck wheel	8,267	58,741	
	Engine	Compression between rear truck wheel and front driver	4,724		
	Drivers	Tension under front driver	5,669		
	Drivers	Compression between front and rear driver	6,377		
	Drivers	Tension under rear driver	4,488		
	Tender	Compression between rear driver and front tender wheel	6,141		89,092
	F. T.	Tension under front tender wheel	4,015		
	F. T.	Compression between front truck wheels	3,779		
	F. T.	Tension under rear tender wheel front truck	3,071		
	Tender	Compression between front and rear truck	5,669	30,351	
	R. T.	Tension under front tender wheel rear truck	5,669		
	R. T.	Compression between front and rear wheels	2,598		
	R. T.	Tension under rear tender wheel	4,960		
Train		Compression between rear tender wheel and car wheel	4,960		
	First Car, Front Truck	Tension under front car wheel	5,196		
	First Car, Front Truck	Compression between front and middle wheel	3,779		
	First Car, Front Truck	Tension under middle wheel	5,669		
	First Car, Front Truck	Compression between middle and rear wheel	3,071	30,351	
	First Car, Front Truck	Tension under rear truck wheel	5,432		
	First Car	Compression in rear of wheel	2,126		
	First Car	Compression in center of space between trucks	2,598		
	First Car	Compression in front of first truck wheel	1,181		66,725
	First Car, Rear Truck	Tension under front wheel	12,754		
	First Car, Rear Truck	Compression between front and middle wheels	3,779		
	First Car, Rear Truck	Tension under middle wheel	6,850	36,374	
	First Car, Rear Truck	Compression between middle and rear wheels	3,779		
	First Car, Rear Truck	Tension under rear wheel	7,332		
		Compression between trucks of first and second cars	1,417		
	Second Car, Front Truck	Tension under front wheel of truck of second car	8,739		
	Second Car, Front Truck	Compression between front and middle wheel	1,417		
	Second Car, Front Truck	Tension under middle wheel	6,614		
	Second Car, Front Truck	Compression between middle and rear wheel	1,417	27,652	
	Second Car, Front Truck	Tension under rear wheel	5,432		
	Second Car	Compression in rear of wheel	708		
	Second Car	Compression in center of space between trucks	2,598		55,171
	Second Car	Compression in front of wheel of rear truck	2,362		
	Second Car, Rear Truck	Tension under front wheel	8,031		
	Second Car, Rear Truck	Compression between front and middle wheel	3,779	27,519	
	Second Car, Rear Truck	Tension under middle wheel	4,253		
	Second Car, Rear Truck	Compression between middle and rear wheel	1,417		
	Second Car, Rear Truck	Tension under rear wheel	6,614		

Empire State Express.—Continued.

			Pounds.	
TRAIN. THIRD CAR.	Compression between rear truck of second car and front truck of third car	2,126		
Front Truck	Tension under front wheel of third car	6,850		
	Compression between front and middle wheel	2,126		
	Tension under middle wheel	6,141	23,738	
	Compression between middle and rear wheel	2,126		
	Tension under rear wheel	4,960		
	Compression in rear of wheel	472		
	Compression in center of space between trucks	472		50,909
	Compression in front of wheel of rear truck	2,126		
Rear Truck	Tension under front wheel of rear truck	10,393		
	Compression between front and middle wheels	2,126		
	Tension under middle wheel	4,724	27,161	
	Compression between middle and rear wheels	2,126		
	Tension under rear wheel	6,377		
	Compression between rear wheel of third car and front wheel of fourth car	1,653		
FOURTH CAR. Front Truck	Tension under front wheel of fourth car	8,267		
	Compression between front and middle wheel	1,653		
	Tension under middle wheel	7,086		
	Compression between middle and rear wheel	1,653	29,170	
	Tension under rear wheel	8,739		
	Compression in rear of wheel	945		
	Compression in center of space between trucks	0		
	Compression in front of truck wheel	1,417		61,528
Rear Truck	Tension under front wheel	8,739		
	Compression between front and middle wheel	2,598		
	Tension under middle wheel	6,850	32,358	
	Compression between middle and rear wheel	2,834		
	Tension under rear wheel	7,794		
	Compression between rear wheel of fourth and front wheel of fifth car	2,126		

Instrument returned to Zero after passage of train.

New York Central and Hudson River Railroad, July 21, 1898.

Ties slightly tamped near stremmatograph.

Rail: 6-*inch,* 100 *pound, outside, on* 3-*degree curve above* 49*th St., N. Y. City.*

Train: No. 57, *Adirondack and Montreal Express, leaving Grand Central Station at* 8.33 *A.M.*

Locomotive: No. 898 ; *weight,* 200,000 *pounds.*

Cars: Baggage, No. 1911 ; *weight,* 53,650 *pounds; Smoker, No.* 2357, *weight,* 51,900 *pounds; vestibule coach, No.* 939, *weight,* 81,400 *pounds; Wagner coaches: No.* 136, *weight,* 96,300 *pounds; No.* 68, *weight,* 103,200 *pounds; No.* 123, *weight,* 95,500 *pounds.*

Speed: 19 *miles per hour.*

Temperature in Rail-head: 110° Fahr.

Adirondack Express.

The apparent mean extreme fiber-stresses per square inch in five inches of the length of the base of the rail were as follows:

				Pounds.		
			Compression in front of truck wheel	4,253	58,700	88,697
Locomotive	Engine	Truck	Tension under front truck wheel	9,684		
		Truck	Compression between front and rear truck wheel	5,196		
		Truck	Tension under rear truck wheel	10,393		
			Compression between truck wheel and front driver	4,253		
		Drivers	Tension under front driver	6,614		
		Drivers	Compression between drivers	2,362		
		Drivers	Tension under rear driver	10,157		
			Compression between rear driver and front wheel of tender	2,598		
	Tender	F. T.	Tension under front tender wheel	7,086	29,997	
		F. T.	Compression between tender wheel and front truck	2,598		
		F. T.	Tension under rear tender wheel front truck	6,141		
			Compression between front and rear tender truck	4,488		
		R. T.	Tension under front tender wheel rear truck	4,488		
		R. T.	Compression between wheels of rear tender truck	1,890		
		R. T.	Tension under rear tender wheel	4,960		
			Compression between tender wheel and front car wheel	3,071	1,535	

New York Central and Hudson River Railroad, September 30, 1897. West Albany.

5-inch 80-pound rail, ties 25-inch centers.
Gravel ballast.

Train No. 5, Locomotive No. 888, Class I., drawing five Wagner palace cars, all 6-wheel trucks, speed 40 miles per hour.

The apparent mean extreme fiber-stresses per square inch in five inches of the length of the base of the rail were as follows:

				Pounds.
LOCOMOTIVE	ENGINE		Compression in front of truck wheel	1,417
		Truck	Tension under front truck wheel	13,070
			Compression between front and rear truck wheel	3,069
			Tension under rear truck wheel	12,579
			Compression between rear truck wheel and front driver	5,433
		Drivers	Tension under front driver	31,415
			Compression between front and rear driver	2,126
			Tension under rear driver	26,456
			Compression between rear driver and front tender wheel	2,362
	TENDER	F. T.	Tension under front tender wheel	12,755
			Compression between front truck wheels	1,181
			Tension under rear tender wheel front truck	13,463
			Compression between front and rear truck	2,362
		R. T.	Tension under front tender wheel rear truck	12,991
			Compression between front and rear wheels	1,889
			Tension under rear tender wheel	12,755
			Compression between rear tender wheel and car wheel	709
TRAIN	FIRST CAR	Front Truck	Tension under front car wheel	14,408
			Compression between front and middle wheel	1,181
			Tension under middle wheel	14,172
			Compression between middle and rear wheel	3,443
			Tension under rear truck wheel	13,224
			Compression in rear of wheel	472
			Compression in center of space between trucks	0
			Compression in front of first truck wheel	945
		Rear Truck	Tension under front wheel	11,337
			Compression between front and middle wheels	2,362
			Tension under middle wheel	12,282
			Compression between middle and rear wheels	1,181
			Tension under rear wheel	12,046
			Compression between trucks of first and second cars	2,362
	SECOND CAR	Front Truck	Tension under front wheel of truck of second car	9,684
			Compression between front and middle wheel	1,181
			Tension under middle wheel	14,172
			Compression between middle and rear wheel	2,126
			Tension under rear wheel	13,463
			Compression in [illegible]	2,126
			Compression in [illegible]	0
			Compression in front of wheel of rear truck	3,071
		Rear Truck	Tension under front wheel	12,046
			Compression between front and middle wheel	1,181
			Tension under middle wheel	18,227
			Compression between middle and rear wheel	2,126
			Tension under rear wheel	11,810
			Compression between rear truck of second car and front truck of third car	3,071
	THIRD CAR	Front Truck	Tension under front wheel of third car	14,172
			Compression between front and middle wheel	1,653
			Tension under middle wheel	15,589
			Compression between middle and rear wheel	708
			Tension under rear wheel	14,644
			Compression in rear of wheel	1,890
			Compression in center of space between trucks	472
			Compression in front of wheel of rear truck	2,126
		Rear Truck	Tension under front wheel of rear truck	9,448
			Compression between front and middle wheels	1,653
			Tension under middle wheel	9,448
			Compression between middle and rear wheels	3,071
			Tension under rear wheel	9,920
			Compression between rear wheel of third car and front wheel of fourth car	2,598

West Albany.—Continued.

Train	Car	Truck		Pounds.
TRAIN	FOURTH CAR	Front Truck	—o Tension under front wheel of fourth car	14,172
			Compression between front and middle wheel	1,890
			—o Tension under middle wheel	12,754
			Compression between middle and rear wheel	2,824
			—o Tension under rear wheel	13,227
			Compression in rear of wheel	2,824
			Compression in center of space between trucks	472
			Compression in front of truck wheel	2,362
		Rear Truck	—o Tension under front wheel	10,393
			Compression between front and middle wheel	2,834
			—o Tension under middle wheel	11,574
			Compression between middle and rear wheel	2,834
			—o Tension under rear wheel	10,157
			Compression between rear wheel of fourth and front wheel of fifth car	4,960
	FIFTH CAR	Front Truck	—o Tension under front wheel of fifth car	16,534
			Compression between front and middle wheel	1,653
			—o Tension under middle wheel	15,117
			Compression between middle and rear wheel	1,653
			—o Tension under rear wheel	15,825
			Compression in rear of wheel	2,126
			Compression in center of space	236
			Compression in front of wheel	2,126
		Rear Truck	—o Tension under front wheel	10,393
			Compression between front and middle wheel	1,653
			—o Tension under middle wheel	12,046
			Compression between middle and rear wheel	1,653
			—o Tension under rear wheel	14,408
			Compression in rear of wheel	1,417
			Instrument returned to Zero after passage of train.	

The fiber-stresses in the base of the rail given for the above trains are the results of the combined static and dynamic effects of the wheel loads.

Over the same rail, as would be expected, the dynamic effects increase with the speed of the train, the minute roughness of the rails, and the increased roughness of treads of the wheels from service.

As the stiffness of the rails increases, the fiber stresses decrease.

To determine the law of the increase of dynamic effects of fiber stresses due to speed alone, trains just from the shops, with perfect wheel-treads, will be required.

New York Central and Hudson River Railroad, September 30, 1897. West Albany.

Train No. 45, *Locomotive No.* 889, *and seven cars, speed* 30 *miles per hour.*

The apparent mean extreme fiber-stresses per square inch in five inches of the length of the base of the rail were as follows:

				Pounds.
Locomotive	Engine		Compression in front of truck wheel	945
		Truck	— o Tension under front truck wheel	7,558
			Compression between front and rear truck wheel	1,181
			— o Tension under rear truck wheel	7,558
			Compression between truck wheel and front driver	1,890
		Drivers	—⊙ Tension under front driver	25,037
			Compression between drivers	4,724
			—⊙ Tension under rear driver	16,298
			Compression between rear driver and front wheel of tender	3,307
	Tender	F. T.	— o Tension under front tender wheel	8,267
			Compression between tender wheel and front truck	2,598
			— o Tension under rear tender wheel front truck	9,448
			Compression between front and rear tender truck	4,015
		R. T.	— o Tension under front tender wheel rear truck	9,920
			Compression between wheels of rear tender truck	4,015
			— o Tension under rear tender wheel	11,337
			Compression between tender wheel and front car wheel	2,834
Train	First Car	F. T.	— o Tension under front wheel of car truck	10,864
			Compression between front and rear wheels of truck	2,598
			— o Tension under rear wheel of truck	10,157
			Compression back of wheel	1,890
			Compression in center of space between trucks	236
			Compression in front of wheel of rear truck	1,417
		R. T.	— o Tension under front wheel of truck	10,393
			Compression between front and rear wheel	2,126
			— o Tension under rear wheel of truck	10,157
			Compression between trucks of first and second cars	3,307
	Second Car	F. T.	— o Tension under front wheel of second car	11,101
			Compression between front and rear wheel	3,071
			— o Tension under rear wheel of truck	13,935
			Compression back of wheel	1,181
			Compression in center of space between trucks	236
			Compression in front of wheel of rear truck	2,362
		R. T.	— o Tension under front wheel of rear truck	10,393
			Compression between front and rear wheel	3,779
			— o Tension under rear wheel	10,157
			Compression between trucks of second and third cars	3,543
	Third Car	Front Truck	— o Tension under front wheel of third car	8,976
			Compression between first and middle wheel	2,362
			— o Tension under middle wheel	10,393
			Compression between middle and rear wheel	2,126
			— o Tension under rear wheel	10,157
			Compression back of wheel	2,126
			Compression in center of wheel space	236
			Compression in front of wheel of rear truck	1,181
		Rear Truck	— o Tension under front wheel of rear truck	9,448
			Compression between front and middle wheels	2,126
			— o Tension under middle wheel	12,046
			Compression between middle and rear wheel	1,181
			— o Tension under rear wheel	12,046
			Compression between trucks of third and fourth cars	945
	Fourth Car	F. T.	— o Tension under front wheel of front truck	13,463
			Compression between wheels of truck	3,071
			— o Tension under rear wheel	15,825
			Compression back of wheel	709
			Compression in center of space between trucks	0
			Compression in front of front wheel of rear truck	1,417
		R. T.	— o Tension under front wheel	16,770
			Compression between front and rear wheels	1,653
			— o Tension under rear wheel	14,408
			Compression between rear wheel of fourth and front wheel of fifth car	708

West Albany.—Continued.

				Pounds.
TRAIN	Fifth Car	F. T.	Tension under front wheel of fifth car	9,920
			Compression between front and rear wheel of truck	1,890
			Tension under rear wheel of front truck	10,393
			Compression back of wheel	1,181
			Compression in center of space between trucks	0
			Compression in front of wheel of rear truck of fifth car	1,181
		R. T.	Tension under front wheel of rear truck	7,558
			Compression between front and rear wheel	1,181
			Tension under rear wheel	8,503
			Compression between rear wheel of fifth and front wheel of sixth car	1,181
	Sixth Car	Front Truck	Tension under front wheel	9,212
			Compression between front and middle wheel	945
			Tension under middle wheel	11,101
			Compression between middle and rear wheel	1,653
			Tension under rear wheel	9,920
			Compression back of wheel	708
			Compression in center of space between trucks	0
			Compression in front of front wheel of rear truck	1,181
		Rear Truck	Tension under front wheel of rear truck of sixth car	9,448
			Compression between front and middle wheel	2,834
			Tension under middle wheel	11,101
			Compression between middle and rear wheel	2,834
			Tension under rear wheel	12,519
			Compression between rear wheel of sixth and front wheel of seventh car	2,834
	Seventh Car	F. T.	Tension under front wheel of seventh car	11,101
			Compression between front and rear wheel of truck	708
			Tension under rear wheel	10,865
			Compression back of rear wheel	708
			Compression in center of space between trucks	0
			Compression in front of wheel of rear truck	2,126
		R. T.	Tension under front wheel	13,227
			Compression between wheels	1,417
			Tension under rear wheel	13,227
			Compression back of wheel	708
			Instrument returned to Zero after passage of train.	

The stresses in the 100-pound rails under the locomotives at moderate speeds, before dynamic effects are generated, show that the total stresses for two locomotives of the same class following one another in a few minutes give close results for the total weights, though stresses per individual wheels will vary several thousand pounds.

The lighter the rails the more marked are the variations per wheel of the stresses under heavy locomotives of 100 tons.

A locomotive of the same class a quarter of a revolution ahead or behind the position of the other locomotive, as it passes over the stremmatograph, will give different individual wheel-stresses, though for slow speeds the total stresses seem to remain practically the same.

In recent experiments it has become necessary to photograph the locomotive as it passes over the stremmatograph, to indicate not only the position of the counterweights in the driving-

wheels, but to note the steam-admission to the cylinder and the varying tractive power in the position of the stroke of the piston.

There are so many complex conditions which affect the stresses in the rails that the static wheel-load does not alone control the individual stresses per wheel.

In rails which are loose the front truck-wheel, in deflecting them to a firmer bearing, often produces as great a stress as a driving-wheel with twice the static load.

Truck and trailing wheels were put under the early locomotives to stiffen the rails for the driving-wheel loads.

The span of the bending rail is influenced by the wheel-spacing as well as the tie-spacing.

In the tests of July 21st on the 100-pound rails a few ties were tamped near the stremmatograph, to see whether or not a slight reduction in the stresses could be made without surfacing several rail lengths.

The stresses for the engine were not reduced, but those for the tender were, while those for the train were increased as the cars were drawn over the slight elevation of the surfaced rails.

The extreme fiber-stresses in the base of the 80-pound rails are much greater than in the 100-pound rails for the same static wheel-loads.

Correspondence-Schools.

BY R. P. ROTHWELL, NEW YORK CITY.

(New York Meeting, February, 1899.)

INSTRUCTION by correspondence is certainly one of the most important and useful of modern educational methods. The paper on the "Scranton International Schools," by Prof. Stoek (Buffalo meeting, October, 1898),* gives an elaborate description of a single private enterprise in this direction, ignoring all others, and cannot be said to present a fair or impartial view of

* *Trans.*, xxviii, 746.

the whole field. To supplement this deficiency, I have prepared the present paper.

There can be no doubt that this method of instruction satisfies a great and keenly recognized need on the part of those, in almost every occupation, who appreciate that knowledge is power, and that the increase of knowledge means increase in the value of service, and consequently in wages. The stoker who understands the principles of the combustion of fuel and the generation and properties of steam can quickly show his greater efficiency in reduced fuel-consumption, better steam-supply, fewer accidents, and longer life in his boilers. If he also studies the construction and working of pumps, he qualifies himself for a higher position and larger remuneration. The charger or roustabout at a smelting-works can similarly advance himself by acquiring a knowledge of the principles involved in the operations with which he is connected. The colliery-miner who understands the composition and properties of the gases given off in coal-mines, the principles of the safety-lamp and of ventilation, and the best means of rescue or remedy for those injured in an accident, is undoubtedly a more efficient and valuable workman than he who acts in ignorance, blunderingly following his ill-understood instructions. The men who have to do with the complicated and ingenious machinery of modern practice, especially in connection with such new agencies as electricity, can unquestionably make themselves more useful, and therefore more valuable, by acquiring special knowledge on these subjects. And how much more successful would be the vast army of sanguine, indomitable and indefatigable prospectors, which covers the mountain ranges from the Yukon to Cape Horn, if all its members were thoroughly acquainted with the origin, conditions, relations and indications of the deposits of useful minerals! It is unnecessary to multipy illustrations of this proposition. Everybody acknowledges that in this age of close industrial competition the intelligence of the workman is the secret, not only of individual advancement, but also of national industrial supremacy. It is, moreover, the most potent factor in the increase of wages, since by increasing the productive efficiency of labor it permits the payment of a larger remuneration.

As a rule, however, the wage-earners in a given occupation,

being dependent upon their daily labor for a living, are utterly unable to take advantage of the instruction afforded by ordinary schools, even when these offer such instruction in the special lines in which they are engaged. Sometimes, moreover, they lack the rudimentary knowledge required as a preparatory qualification for technical schools, or they have a natural dislike to the exposure of their ignorance in such respects before classes of younger, but more favored, persons.

But this is not all. Not a few persons, well-grounded in general education, and even in certain branches of higher and technical training, find themselves in positions of responsibility in which they feel the need of knowledge in some special branch not included in their previous studies. This is peculiarly the case in the United States, where men of education and executive ability frequently change their special occupations. This is by no means a sign of inferiority in our system of technical organization. The personal qualities of integrity, industry, skill and experience in the management of workmen, wisdom and decision in the direction of business, etc., are really rarer and more valuable to capitalists than a mere knowledge of technical details, unaccompanied by such qualities of personal character. Hence it often happens that men of demonstrated ability are called to manage, and do successfully manage, business enterprises, the technical details of which they have yet to learn. This is especially true of the managers of mining companies, who frequently have charge of concentrating-works, mills, furnaces, railroads, ditches, cable and electric lines, etc., as well as of the ordinary operations of mining. A man may be an accomplished engineer in some of these directions without having had instruction and experience in all. And such men often desire earnestly to learn, in this or that branch, at least enough to enable them to direct and judge intelligently the work of their subordinates. Yet they cannot abandon their work and go back to school for such a purpose.

To both these classes—the workmen who need to learn the rudiments of theory, and even, perhaps, to acquire the fundamental means of all technical study, such as arithmetic and the ability to interpret and to make working-drawings, and also to the educated engineers who desire to fill up gaps in their

knowledge—the correspondence-school offers its aid. Its method of instruction may be summarized as follows, some observations and criticisms upon details being reserved for statement later in this paper.

The only indispensable prerequisite on the part of the student is the ability to read and write fairly well. All students who start from that point pursue certain courses in arithmetic, and, if necessary, in algebra and higher mathematics. This is done by means of instruction-papers and question-papers mailed to the student; the former containing the principles and data upon which the latter are to be worked out. The question-papers with their problems worked out in detail are returned to the school, examined, criticized, returned for further work if necessary, and so on, until the answers of the student to a given question-paper exhibit a certain grade of efficiency, after which another instruction-paper and another question-paper follow. (At the outset two different papers of each kind are sent, so that, thereafter, the student may always have a set on hand to work upon, while a question-paper with his answers is under examination at the school.) At the end of a given course thus conducted a certificate is given to the student.

The success of such instruction depends largely upon the diligence of the student, and it is directly to the business interest of the school that he should be urged to earnest work, and helped in case of difficulties or discouragements; for the diligent student is the one who makes rapid progress, feels satisfied with the results attained, pays his dues promptly, and recommends the school to others, both by his good word and by his success. The constant stimulation of the student, and the small number of instruction-papers given out at one time, tend to make many persons study who would turn away in despair or indifference from a ponderous volume containing all the instruction-papers of a whole course, or from an ordinary text-book intended for use in the presence of a competent instructor.

It is, in my opinion, a great advantage to the new method that practically all the correspondence-schools are private business enterprises, conducted for the purpose of making money. This advantage is seen in part in the rapid multiplication of such schools, and the sharp competition which is beginning to

arise among them, involving an amount of vigilant criticism on the part of rivals not commonly indulged in among regular colleges and universities, which pay no dividends. Moreover, the fact that under this system the student is a customer, operates to secure for him honorable and liberal treatment. Thus all the schools allow students who have paid for a full course or scholarship to continue their studies, whether interrupted or not, so that it may be many years before they finally pass creditable examinations and receive corresponding certificates in the subjects, for instruction in which they have paid. Nearly all permit a student who is prevented from continuing a course for which he has paid the full fee, to sell or transfer his scholarship to another. In fact, the solicitors for the several schools already vie with one another, and will doubtless do so in increasing degree, as competition increases, in offering convenient and liberal terms to students.

It may be presumed that the open competition of the schools, insuring constant criticism and comparison of their instruction-papers, and of the value of the instruction otherwise given, will effectually prevent any deterioration of educational efficiency. Not only will the fittest survive, but the less fit will promptly succumb under this intense competition and vigorous criticism of their rivals.

That there is a temptation to make money too quickly by devices injurious to the highest educational efficiency cannot be denied. I think this tendency has already induced, for instance, the selling of bound volumes of instruction-papers, and even of "keys" to the question-papers, both of which practices are to be disapproved. Such bound volumes cannot be "up to date," as it is necessary to keep the separate instruction-papers in order to secure one of the great advantages of this system. And evidently the use of keys is utterly destructive of the foundation of efficient instruction and real progress on the part of the pupil under this method. The granting of certificates to unqualified pupils is another danger which has already shown itself in one, at least, of these schools. It must be remembered that in proportion as the certificates earned by earnest and honest students prove valuable to the holders as wage-earners, they will be sought after by others who

will not hesitate to cheat by the use of "keys" in order to obtain them.

There is also a temptation to inflation of the capital of such enterprises. The enormous increase of the capital stock of the Scranton schools, for example,—from $100,000 to $1,250,000 in seven years,—is soon followed by the announcement of a further increase to $1,500,000. In this instance every new issue of stock has been sold for cash at par, and the money has gone in some way into the business, from which large dividends have been paid. But a business of this kind is peculiarly liable to self-deception in bookkeeping. New capital may be invested in replacing plant already representing former capital; and the regular balance-sheet may thus come to overstate the real assets. A paid-up capital, a large amount of which is represented by such items as "good-will" or "earning-power," is a snare into which stock-companies too often fall; and the increase of capital by "construction" and "improvement" accounts which should have been carried as part of current expenses, has been notoriously the cause of disaster to innumerable railroad and manufacturing companies. The desire to pay large dividends is acknowledged to have been the cause of such fallacious bookkeeping. So far as the Scranton schools are concerned, it is, of course, primarily the business of the stockholders in that company to look after their own property, and if they are satisfied no one else is responsible. But from the standpoint of the friends of the correspondence-system of education it is permissible to express the belief that this particular enterprise is excessively and unwisely over-capitalized, and that such a course invites evil results which would discredit, however unjustly, the whole correspondence-system.

The rapid expansion of the Scranton schools, proving as it did the public appreciation of the correspondence method, has led to the establishment of many such enterprises, of which I propose to give a brief account. No doubt others will spring up; and some among them will probably be mere catchpenny schemes, like the notorious "paper" medical and other colleges. But those which I shall name are, so far as I know, conducted efficiently and in good faith.

The claim is advanced by some of them that their papers

and methods are improvements upon those of the Scranton schools; and it is reasonable to suppose that in such a competition the later comer may have taken advantage of the experience of his predecessors, and adopted features which are, for the time being, at least, superior. It may safely be assumed that not one of the correspondence-schools has yet reached perfection in any of its departments, or, for that matter, ever will do so: for progress is inevitable, and one of the claims made for these schools is that they are "kept up to date."

In considering the more important American correspondence-schools, I shall specially mention those which have engineering courses. It should be added that the tendency is already well developed to include in a single such enterprise instruction in all subjects for which there seems to be a paying demand. The extra cost of advertising and instruction is small in proportion to the extra profit, and the schools tend to become "department-stores" of vast and varied scope.

The following is a list of the more important schools, arranged alphabetically:

1. American School of Correspondence, of Boston, Mass.
2. American Correspondence-School of Textiles, of New Bedford, Mass.
3. Electrical Engineer Institute, of New York City.
4. Institute for Home Study of Engineering, of Cleveland, Ohio.
5. International Correspondence-Schools, Scranton, Pa.
6. National Correspondence Institute, Washington, D. C.
7. Railway Correspondence-School, New York City.
8. Sprague Correspondence-Schools, Detroit, Mich.
9. United Correspondence-Schools, New York City.

There are a number of correspondence-schools of law, of medicine, and of literature, such as the Chautauqua school, which has been taken over by the University of Chicago, and the "Cosmopolitan University," which is a correspondence-school of literature organized by the *Cosmopolitan Magazine*.

There are three correspondence-schools of mining in England; but they are not important.

1. The American School of Correspondence, of Boston, Mass., has a very distinguished board of officers and in-

structors, men well known in the engineering professions. The courses taught by it are six, namely, in stationary, locomotive, mechanical, marine and electrical engineering, and mechanical drawing. This school lays special emphasis on the fact that it is devoted strictly to the study of steam and electrical engineering and the construction and operation of machinery, and upon the high professional standing of its officers and instructors. It has the elements of success, and appears to be conducted honorably and with intelligence.

2. The American Correspondence-School of Textiles has entered a very useful field, though it is somewhat foreign to our Institute of Mining Engineers. As the school is under the directorship of a competent and experienced gentleman, Mr. C. P. Brooks, it will doubtless make a success, and will be of great benefit to the industry to which it is devoted.

3. The Electrical Engineer Institute of Correspondence-Instruction, of New York, connected with the *Electrical Engineer*, is devoted to instruction in electrical engineering in its various branches. The instruction covers arithmetic, mensuration, algebra, physics, chemistry, mechanics, mechanical drawing (optional), principles of electricity and magnetism, instruments and measurements, continuous-current machinery (optional), and electro-metallurgy. This school lays special stress on its reference, by permission, to a long list of well-known electrical engineers as to its good faith, trustworthiness and technical reliability. It also refers to letters from its students as to the satisfaction given in the methods of instruction and treatment generally.

4. The Institute for Home Study of Engineering, of Cleveland, Ohio, includes also the Correspondence-School of Technology of Cleveland, these schools having been united. This school is six years old, and is the oldest correspondence-school in this country, including instruction in electricity. It is devoted exclusively to the study of engineering, and its courses are arithmetic, algebra, geometry, trigonometry, physics, mechanical drawing, shop, steam engineering, electrical engineering, electrical-mechanical engineering, surveying and railroads, bridges, roofs and structures, hydraulic engineering and ad-

vanced mathematics. This school has several well-known engineers as heads of departments.*

5. The International Correspondence-Schools of Scranton, Pa., has courses in arithmetic, mensuration, mechanics, geometrical and mechanical drawing, mining, mechanics, steam engineering, electricity, architecture, plumbing, heating and ventilation, civil engineering, railroad . . bridge engineering, municipal engineering, hydraulic engineering, English branches, bookkeeping and stenography, sheet-metal pattern-drafting, pedagogy and chemistry.

6. The National Correspondence Institute, Washington, D. C., has been in operation about six years. It gives instruction in seven different departments, besides the usual preliminary courses in arithmetic, algebra, etc., which are common to all the schools. The departments taught are engineering in all branches, science, journalism, English, bookkeeping and business, shorthand- and type-writing, and preparations for civil service and other examinations. The last department appears to be that which receives the chief attention and has the largest number of students. The faculty of this school contains a number of graduates from our leading colleges and universities, and the school under them is doing good work, to the satisfaction of its students.

7. The Railway Correspondence-School of New York is a young and modest institution, which is devoted to giving instruction to locomotive engineers, firemen, railway mechanics, trainmen and trackmen. The courses cover fifty lessons each, and appear to be well adapted to the classes addressed.

8. The Sprague Correspondence-Schools, Detroit, Mich. This institution has a school of law and also one of journalism. It is one of the older correspondence-schools, and is very pushing and enterprising in its business methods, and apparently successful in its educational features.

9. The United Correspondence-Schools, of New York City. This institution, though young, is of greater interest to the members of the American Institute of Mining Engineers than any of the others, because it is devoting special attention to in-

* Since this paper was in the printer's hands this school has been sold to and consolidated with The United Correspondence-Schools of New York.

struction in mining, metallurgy and kindred subjects. The courses of study include the usual subjects—arithmetic, algebra, logarithms, geometry, mensuration, trigonometry, geometrical and mechanical drawing; and the engineering courses comprise electrical engineering in all its branches; mechanical engineering; steam engineering: civil engineering, including hydraulic, municipal, railroad and bridge engineering; surveying and mapping; sanitary engineering, including plumbing, drainage, heating and ventilation; gas-fitting. There is a school of art and architecture, and there are schools of trades, including sheet-metal workers, pattern-makers, etc. The school of mines includes geology, mineralogy, assaying, ore-deposits, prospecting, coal- and metal-mining, ventilation of mines, mechanical engineering of mines, metallurgy of all the metals, electrometallurgy, etc. These courses are new, and the students enrolled are as yet in the preliminary subjects. The preparation of the instruction-papers and the care of the students are in the hands of experienced and practical mining engineers of high standing in the profession.

There is also in formation a very important "School for Practical Newspaper-Workers," in which, besides the training of pupils for strictly newspaper-work, instruction will be given in the preparation of such statements and descriptions as are required for scientific and technical papers; in the suitable preparation of manuscript for the printer, and in the reading of proof, etc. These courses will be conducted by eminent literary authorities connected with the New York press, who will teach the practical work in every department of a newspaper.

It is not too much to say that this is the one department in which most engineers, however otherwise accomplished, are deficient. Many who are high authorities in theory and practice keenly feel their lack of the art of stating with correctness and convincing force, and preparing completely for publication, the results of their study and observation, and will welcome an agency by the help of which they can supply this deficiency without interrupting their professional work.

Since this paper was announced, the writer has become personally interested in the United Correspondence-Schools, and naturally entertains a favorable opinion of them, although, in

fact, that opinion should be considered as the cause, rather than the result, of his participation in the enterprise. The schools were founded in 1897 by Mr. F. W. Ewald, who, in 1892, left the machine-shops of the Dickson Manufacturing Co., at Scranton, to take the technical direction of the Scranton correspondence-schools. This difficult position in a new field he occupied for five years, and under his direction the Scranton schools established themselves successfully. It is one of the regrettable results of the business aspect of this subject that Prof. Stoek did not see fit to recognize in his paper the services which Mr. Ewald had rendered as a pioneer in a new educational method. If he had been writing a purely scientific review of the history of any improvement in the arts he would doubtless have made cordial mention of one who had contributed to its progress; but the courtesies of business do not, it appears, include praise of a competitor.

Of course, Mr. Ewald believes that, profiting by his past experience, he has been able, in organizing these schools, to avoid errors of judgment already demonstrated, and to make the new courses better than those previously prepared under his direction. However reasonable this and other claims may be, they cannot be settled by assertion and counter-assertion. The only test is the careful comparison of means and results.

A few particulars may be pointed out as points of critical value in such a comparison.

Instruction-Papers.—The instruction-papers of the correspondence-schools are naturally based on standard text-books, and on periodicals devoted to the respective specialties concerned. But neither text-books nor periodicals are free from errors and inconsistencies; and the instruction-papers must be prepared by experts not only competent to criticize and correct, but also able to make the result clear, accurate and complete. For, in the vast majority of cases, these papers are sent to persons to whom general and special authorities are not accessible, and perhaps would not be comprehensible. The reference of the student to printed books for information not clearly given in the papers he receives is clearly impracticable. It would increase his expense and labor, discourage his endeavor, and lose his "custom." Hence, the instruction-papers must be complete in themselves, giving all the information necessary for the work

Of course, they should be accurate; but they ought, in addition, to be uniform. The great cost of answering separately individual letters of inquiry makes every obscurity or inconsistency in an instruction-paper fatally expensive. If the weight of a cubic foot of water is stated in one paper as 62½, and in another as 62¼ pounds, or if, in a machine-drawing, it is not clear whether a certain piece is a bolt or a screw, and if, at different times, 10,000 students separately want to know which is correct, the trouble and cost of the necessary explanations would be ruinously large, and the certainty of its indefinite continuance, together with the injury to the student's trust in the school involved in every confession and correction of an error in its instruction-papers, would dictate the cancellation of the papers thus found unsatisfactory, and the issue of a new edition. It is, in any event, continuously and imperatively necessary for all such schools, large or small, to revise and re-issue instruction-papers, bringing them up to date in accuracy and completeness. They do not all, however, fulfil this requirement.

Revision of Question-Papers.—The first examination of the work of a student upon the question-paper is performed by employees (mostly young women) not capable of solving difficulties or giving instruction, who simply mark it according to a "key," which gives the correct answers called for by the question-paper. It is scarcely fair to include as "instructors" the persons who perform such purely clerical duty, as is done in Prof. Stoek's paper. The real instructors are those to whom, in each department, difficulties and inquiries are referred; and these are comparatively few.

The Future of Correspondence-Instruction.—In view of the undoubted value of correspondence-schools, and the reception which they have experienced from the public, they will undoubtedly not only continue, but multiply; yet there are limits to their probable increase. Their scale of charges is low. They are like mills running on low-grade ore, of which the supply is practically unlimited, but the treatment leaves only a narrow margin of profit, and they must, therefore, be carried on upon a large scale, with adequate capital and with business sagacity. The example of the success of the Scranton schools is not so encouraging to imitators as many persons suppose.

The financial success of the correspondence-schools depends very largely upon advertising and soliciting, after the manner of life-insurance companies. The advertisements in technical and trade papers attract many, who are thus brought to understand that they can increase by this means their earning-capacity, while the ubiquitous canvasser, whose remuneration is a commission on the students enrolled, employs the arts with which we are all familiar to convince the wage-earner that more knowledge means greater efficiency and higher pay; and that the school he represents affords superior advantages to any other. In this way the correspondence-schools are not only supplying useful knowledge to thousands of wage-earners and others who have the desire to improve, but cannot avail themselves of existing facilities; they are also arousing tens of thousands, who had never felt this desire, to an appreciation, an aspiration, and a resolve, to which they might otherwise remain wholly indifferent.

Since nearly every occupation that men and women follow is a fit subject for correspondence-instruction, greatly increasing their efficiency and earning-power, this new development of educational methods is, in my opinion, one of the most important and beneficial that has ever been undertaken, and is bound to exercise a vast influence upon the industrial development of nations. The benefit of the technical education of the masses has been gaining recognition in every civilized nation, as witness the many free schools of science and art and of manual training, established in this and other countries through private or public munificence. But in this, as in other matters, private commercial enterprise is much more efficient and more useful than public subsidized institutions; in the first place, because, in general, men rarely appreciate what they get for nothing; secondly, because private enterprise is bound to furnish what is of most practical value to the people addressed, or it loses its investment. It is, as it were, under bond, to the amount of that investment, to give good value for what it receives; while public appropriations, and often private contributions, to "institutions of learning," go on, whether the institution gives value for what it receives or not. Private initiative and enterprise devoted to making money while supplying a public want, which possibly they have themselves created, are

always more beneficial in their results, and these are more highly appreciated by those for whom they are intended than is *free* instruction paid for by the State, that is by all the people.

But correspondence-instruction is not, and cannot become, the equivalent of thorough education in our great technical schools. No such comparison should be made. The two methods address quite different classes, and are adapted to persons studying under altogether different conditions. The correspondence-school addresses chiefly those who are assumed at the outset to know only how to read and write, and who can devote to study at most only their evenings, holidays, and odd hours during one, two, three or four years, while engaged in the engrossing pursuit of their daily bread-winning occupation. They could not understand, and do not need, the higher instruction given in ordinary text-books; and the time they have to devote to the study of a subject is probably not more than from one-tenth to one-fiftieth what is necessary for a student in one of our excellent technical schools. The objects and necessary methods of instruction of the classes addressed are not comparable. The correspondence-school will teach a hundred where the technical school teaches one. It does not pretend to give as thorough instruction; but, in the aggregate results of its influence on the betterment of the condition of the wage-earning classes, it may compare very favorably with the technical schools or colleges of the country. To disparage it would be as irrational as to condemn hydraulic mining which melts away mountains, and earns dividends out of material yielding but four cents of gold per cubic yard, because it does not compare in the percentage saved with the treatment of gold-ores by chlorination or cyaniding. Correspondence-instruction is a process for the treatment of low-grade material, the supply of which is practically unlimited. It is adapted to the "handling" of immense quantities at low cost, and, though its efficiency is not as high as that of more expensive processes, its aggregate returns are immeasurably great and of real profit to the community.

A Decade of Progress in Reducing Costs.

BY CHARLES KIRCHHOFF, NEW YORK CITY.

(Presidential Address at the New York Meeting, February, 1899.)

FOR twenty years it has been my work to watch and record progress in both the technical and the commercial branches of mining engineering in the wide sense in which it is represented by our Institute. While you who have been actively engaged in our profession have made history, a few of us have attempted to be the historians and have been kept keenly on the *qui vive* to follow the developments of so broad a field. One so employed may be pardoned if he ask you to pause for the unusual purpose of looking backward, that you may measure what you and others have done, and that the younger men may gather inspiration from the work accomplished by their elders and their predecessors.

It is not so long since that the commercial management dominated our industries. Bred in the school of science, which seeks its reward in establishing the truth, our engineers were sometimes indifferent to trade conditions and requirements. Much of that feeling has disappeared, and the engineer recognizes that it is his mission to apply the achievements of science to a useful commercial end. On the other hand, business men now understand that the utilization of our natural resources and the production of articles for consumption is impossible without the intervention of the engineer. They must co-operate, unless, indeed, the two functions are combined in one man —a rare but powerful combination.

Now the final measure of success of both is the cost sheet on the one hand and the expansion of markets on the other, so closely interwoven, so mutually interdependent. There is one cardinal feature, however, which characterizes the engineer's work—namely, the permanence of his achievements. Every improvement, particularly when it has been recorded in such lasting form as a paper in the *Transactions* of our societies—

every improvement represents an advance from which there is no receding. It means that ground has been conquered which will never be surrendered. From time to time we have epoch-making discoveries which advance the art at a bound, but I venture to assert that in the aggregate greater progress is made in the direction of reducing costs by minor improvements in practice and equipment.

It is my purpose to present some data which shall reflect that movement, and indicate to what extent it has been responsible for the rapidity with which we have conquered and are now fortifying our position as contributors to the world's requirements. The most convenient method for such an estimate naturally is to follow the course of prices, but this does not go below the surface. A comparison of costs strikes deeper because it may be expected to reveal in what directions most has been accomplished, and along what lines further development is possible and profitable.

Now, of course, we all know that to the producer nothing is usually more sacred than his cost sheet, and it is not easy for an outsider to get frank and accurate statements of this class. But there is less difficulty in obtaining a statement showing relative figures. A number of concerns have furnished to me reports showing in percentage of the costs of a base year how the outlays varied for a series of years, and these I shall use in the present occasion, without giving the names of the respective establishments.

It may be urged that one serious defect is inherent in any method possibly employing data obtained from plants of comparatively greater age. The point will be naturally raised that individual concerns may not have kept up with the times in equipment, and possibly, in practice; that those who were banner-bearers of progress five or ten years since have, involuntarily or otherwise, resigned the leadership to younger rivals, the shortness of whose career excludes them from those who have made history for a whole decade. The assertion seems plausible that the results based upon the returns from individual producers do not necessarily reflect the entire advance accomplished in a decade.

Such objections can, frankly, be only met with the necessarily vague and therefore partially unsatisfactory reply that

the concerns selected are among the largest, and are believed to be in the front ranks of the progressive producers of this country. There must be coupled with this assurance the disclaimer that the results possess value beyond that of being illustrative of the progress made. The absence of any such statistics gives those presented a value. However keen might be the desire to expand and multiply them, it must give way to the practical difficulties of collecting them and interpreting them in detail without revealing their origin. A further objection might be that the results obtained may be exaggerated, because it was only the stress of the struggle during recent years which brought into line with modern practice plants whose management was not up to standard during the entire years of the decade.

Statistics of this scope tell only a part of the story, because they must naturally be restricted to those operations and plants in which revolutionary changes in methods have not been introduced to defeat comparisons. If we were to trace the lowering of cost of Western copper for the whole decade, we must naturally stop with the matte, since Bessemerizing is of only recent introduction, and was at first developed tentatively.

There are few open-hearth plants more than ten years old which have not in that time swung wholly or partially from the acid to the basic process.

Valuable though they be, statistics of this character can only partially express and reflect progress. Figures bearing on cost of product deal with the article manufactured only with reference to quantity. They fail to show how the standard has been raised as to quality—both as to excellence and as to uniformity. Data bearing, for instance, on the percentage of seconds in a rail-mill, or rejections in rolling-plates, structural material or bars, might be convincing as to a part of the progress effected, and yet would tell only a part of the truth because specifications have become more stringent and inspection more severe and searching.

The general proposition is true, therefore, that we can only reflect in statements of cost a part of the achievements of the American mining engineers and metallurgists of the past decade, and that an important though undefinable addition thereto has been conquered in the form of a fuller utilization of raw

materials, of more effective handling of labor, of increased safety to men and plant, of heightened quality and uniformity of product, of greater regularity of employment of equipment, and of prompter and more certain filling of consumers' orders. It need hardly be pointed out that improvement along these lines is as real an advance as is the crowding down of fuel or labor cost, and it will be frankly acknowledged by the engineer that the co-operation of the commercial management must be credited with a large share of it.

All these factors tell upon the balance-sheet, which, after all, is the most important document for the engineer to study. While he is usually more intimately and directly concerned with the expenditures, he does and should influence the receipts through quality of product and promptness and reliability of deliveries.

Now that the American mining and metallurgical industries have stepped into the world's arena, our engineers have had placed upon their shoulders the greater responsibilities which come with wider opportunities. The reproach has been often made that we are lavish, if not reckless, with our natural resources. Few will deny that there has been much justification for this reproach in the past, and that in some respects we are still at fault. While it is true that there were times when it did pay to waste, it is certain that these days are passing. We may be justly proud of the vast resources with which this country has been blessed. But far greater glory than mere pride of possession is that of having successfully striven to develop to the utmost the opportunities thus accorded to us for the good of our country and of mankind. To contribute to that end has been both the aim and the achievement.

Cost of Pig-Iron.

Permit me to submit first the following table, showing the fluctuations in the cost of making pig-iron of a large furnace plant in the South. (See page 356.)

These figures have been plotted on the accompanying diagram, in which, for convenience sake, the fluctuations in the daily product have been started from the base line. (See Fig. 1.)

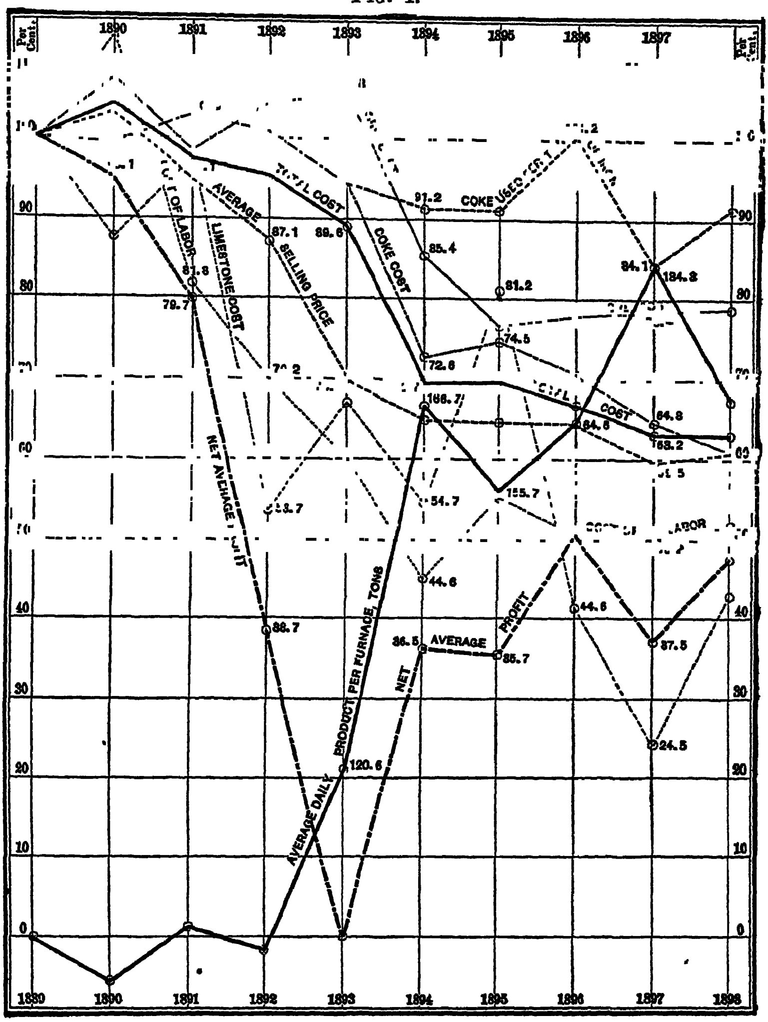
Comparative Statement of Pig-Iron Costs for the Years 1889 *to* 1898, *Both Inclusive, with the Figures of* 1889 *taken as a Unit Basis.*

Year.	Product per Day, Tons, Per Cent.	Coke Consumption per Ton Iron, Per Cent.	Ore Cost, Per Cent.	Limestone Cost, Per Cent.	Coke Cost, Per Cent.	Labor Cost, Per Cent.	Cost of Arbitraries, Per Cent.	Cost of Sundries, Per Cent.	Total Cost, Per Cent.	Average Selling Prices, Per Cent.	Net Average Profit, Per Cent.
1889........	100	100	100	100	100	100	100	100	100	100	100
1890........	94.1	99.4	107.6	87.6	99.4	112.8	103.3	105.8	104.3	103	95.1
1891........	101	102.3	98.22	97.6	102.8	81.8	103.3	99.6	97.1	94.6	79.7
1892........	98.1	100.6	104.5	53.7	100.8	70.2	106.6	112.2	95.1	87.1	38.7
1893........	120.6	94.7	105.8	67.1	94.6	60.5	100	90.8	89.6	76.9	......
1894........	166.7	91.2	85.4	54.7	72.6	44.6	88.3	70.1	69.7	65	36.5
1895........	155.7	91.2	76.6	81.2	74.5	55.3	95.6	47.1	69.8	64.9	35.7
1896........	164.4	101.2	78	41.6	70.6	50.9	127	42.1	67	64.6	50.8
1897........	184.3	84.1	78.4	24.5	64.8	50.2	116.6	37.4	63.2	59.5	37.5
1898........	167.7	91.2	79	40.3	64.1	51.9	113.3	33.4	63.4	61.2	47.9

MEMORANDA.—Only 11 months included under 1898, January to November inclusive. Arbitraries cover relining charge, general office expense, taxes and insurance. Sundries cover sand, brass and iron castings, coal to locomotives and engines and boilers and pumps, all small tools and furnace supplies.

This series is particularly interesting, because the cost of freights on assembling materials, which is the dominating factor in the production of pig-iron in other sections, is relatively of little importance to the southern producers. On that ac-

FIG. 1.



Fluctuations in Cost of Production of Pig-Iron.—Southern Plant.

count the record shows strikingly, in the absence of that modifying factor, what has been achieved in the direction of lowering costs through improved practice in the preparation of materials and smelting.

In other sections of the country the rapid decline in the cost and in the charges for the transportation of ore by land and on the lakes, and for the carriage of fuel, has been a very important item in the cost account. In the South, credit for what has been accomplished need not be divided by the iron-maker with the carrier.

It will be observed that there was a pronounced fall, notably in 1894, and that now, in recent years, the cost is only about 63 per cent. of what it was in 1889. As the largest single item the coke cost is the most worthy of study, and here we have the interesting observation that while the cost per ton of product has been reduced to 64 per cent. of that of 1889, the consumption, so far as quantity comes into play, has undergone only a moderate reduction—a fact which comes out clearly in the case of other furnace returns. In the South, very important progress has been made in the preparation of the coal for coking, which has favorably affected cost in other directions, too.

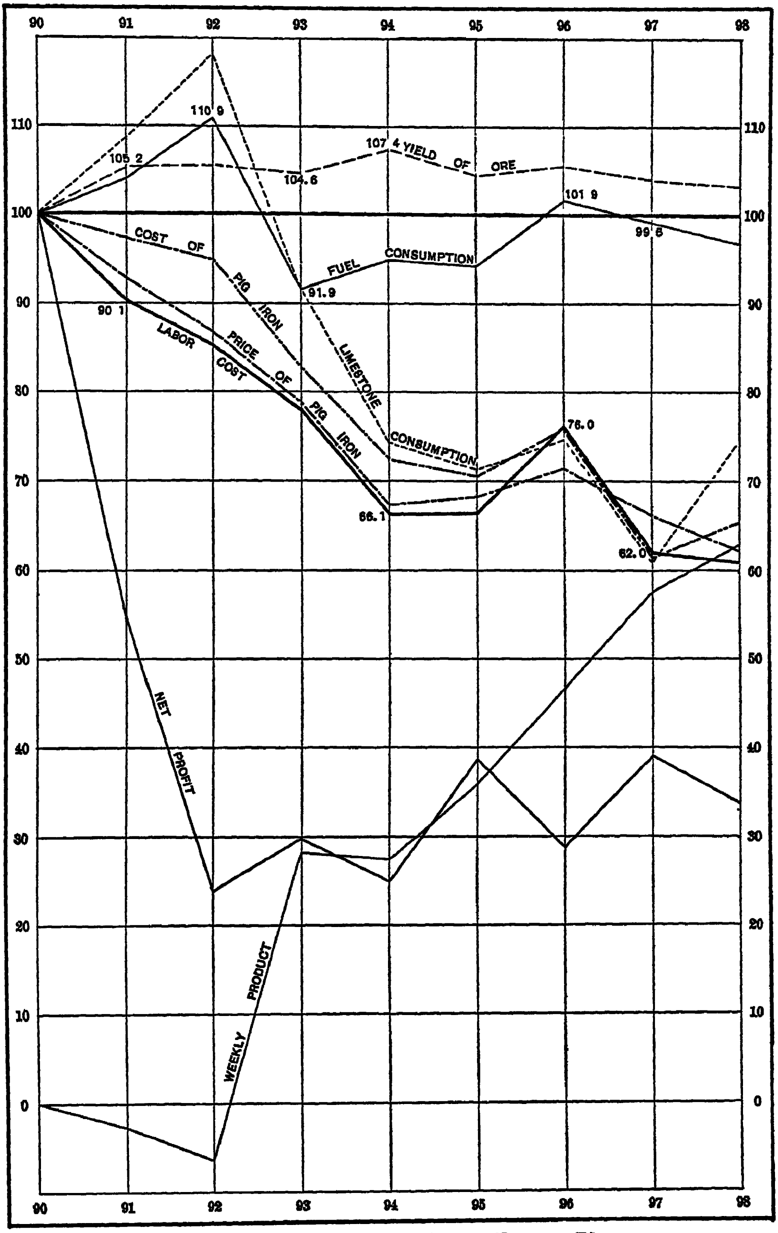
The lines of cost of ore and of limestone show somewhat curious irregularities, which are due to the fact that the burden has changed. In the earlier years a large percentage of soft ores was used. Since these carried no lime, the cost for stone was consequently larger during that period. In the more recent years a much larger percentage of calcareous ores was charged, so that practically the cost of limestone has been eliminated, since for prolonged periods no stone whatever enters into the burden.

The labor cost has been cut down to about one-half, that and the minor items of cost, like "sundries," being largely affected by the output, whose growth is clearly shown in the line starting from the base. The daily output nearly doubled during the decade under review.

An additional line of very great interest may be referred to, and that is the one giving the fluctuations in the selling price and the line bearing on profits. The former shows a greater decline than the cost line, so that the profit was at all times less. The year 1893 carried it down, so that it was only slightly above the zero line, and altogether it shows the most extraordinary irregularities.

I am indebted to the manager of what is regarded as the

FIG. 2.



Fluctuations in Cost of Pig-Iron.—Eastern Plant.

best-handled furnace-plant east of the Alleghenies and north of the Potomac for the following data, based upon the work done in the year 1890, which, owing to a combination of circum-

Comparative Statement of Pig-Iron Costs, 1890 *to* 1898 *Inclusive,* 1890 *taken as a Unit Basis.*

Year.	Product Per Day.	Fuel Per Ton of Iron, Pounds.	Ores Per Ton of Iron, Per Cent. Yield.	Limest'ne Per Ton of Iron, Pounds.	Wages for Labor.	Incidental and Office Expenses.	Average Price of Iron, f. o. b Furnace.	Cost of Ores, Fuel, Stone, Wages, Incidentals and Office Expenses.	Net Profit.	
1890..............	100	100	100	100	100	100	100	100	100	
1891..............	97.2	104	105.2	108.4	90.1	101.5	92.5	97.2	54.4	
1892..............	93.6	110.9	105.7	118	85.1	106.1	86.6	95.1	23.9	Running nine months, repairing, etc.
1893..............	128.0	91.9	104.6	91.5	78	81.5	77.8	83.1	29.7	
1894.........	127.5	94.9	107.4	74.1	66.1	83.1	67.3	72.4	24.9	
1895..............	135.9	94.3	104.2	71.7	66.2	76.9	68.2	70.7	38.9	
1896..............	128.0	101.9	105.7	74.7	76	92.3	71.7	75.7	28.5	Running eight months, repairing, etc.
1897..............	157.8	99.6	104.0	60.9	62	69.2	66.1	69.9	39.3	
1898..............	163.3	97	103.7	74.5	61.1	70.6	62.2	65.8	33.9	

stances possibly not general, was the most profitable year encountered. The accompanying diagram furnishes a ready means of grasping the main points. (See Fig. 2.)

The plant was stopped for three months and four months respectively in 1892 and 1896 for repairs, which affected cost, notably in the latter year. Improvements and betterments are not included in the cost of the iron.

It will be observed that the total cost of materials, wages, incidentals and office expenses has been quite sharply reduced, in spite of the fact that the quantity of fuel consumed has undergone but little reduction during the past decade. The labor cost has been reduced nearly 40 per cent. The output per day showed a sudden increase in 1893, and has developed very rapidly since that date.

A third series of records is that dealing with the results of a large works in the Pittsburgh district, which deals with the following items:

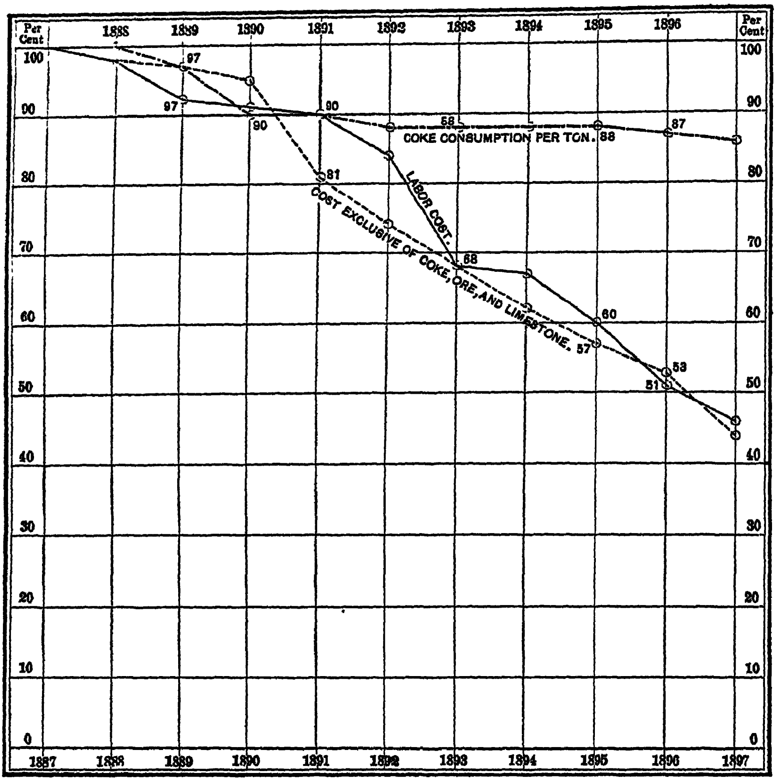
1. The comparative cost of labor.
2. Total cost of making pig-iron, exclusive of cost of ore, coke and limestone, but including labor, materials for repairs, running expenses, fuel for steam, etc.
3. Coke consumption per ton of pig-iron.

Year.	No. 1. Labor Cost. Per Cent.	No. 2. Cost Exclusive of Raw Materials. Per Cent.	No. 3. Coke Consumption. Per Cent.
1887	100	100	100
1888	98	98	100
1889	92	97	96
1890	91	95	90
1891	90	81	90
1892	84	74	88
1893	68	68	88
1894	67	62	88
1895	60	57	88
1896	51	53	87
1897	46	44	86

The most striking facts are that a relatively considerable saving has been effected in the consumption of fuel, that the labor cost has been crowded down to less than one-half, and that the cost of converting the raw materials into pig has been lessened even more. Since this plant uses almost exclusively

lake ores, the cost of material has, of course, also undergone a very sharp reduction. The figures submitted, however, prove that the practice has achieved some very excellent results quite apart from economies due to lower cost of raw materials at point of shipment, and decreased cost of assembling, through reduction in lake and inland freights. (See Fig. 3.)

Fig. 3.

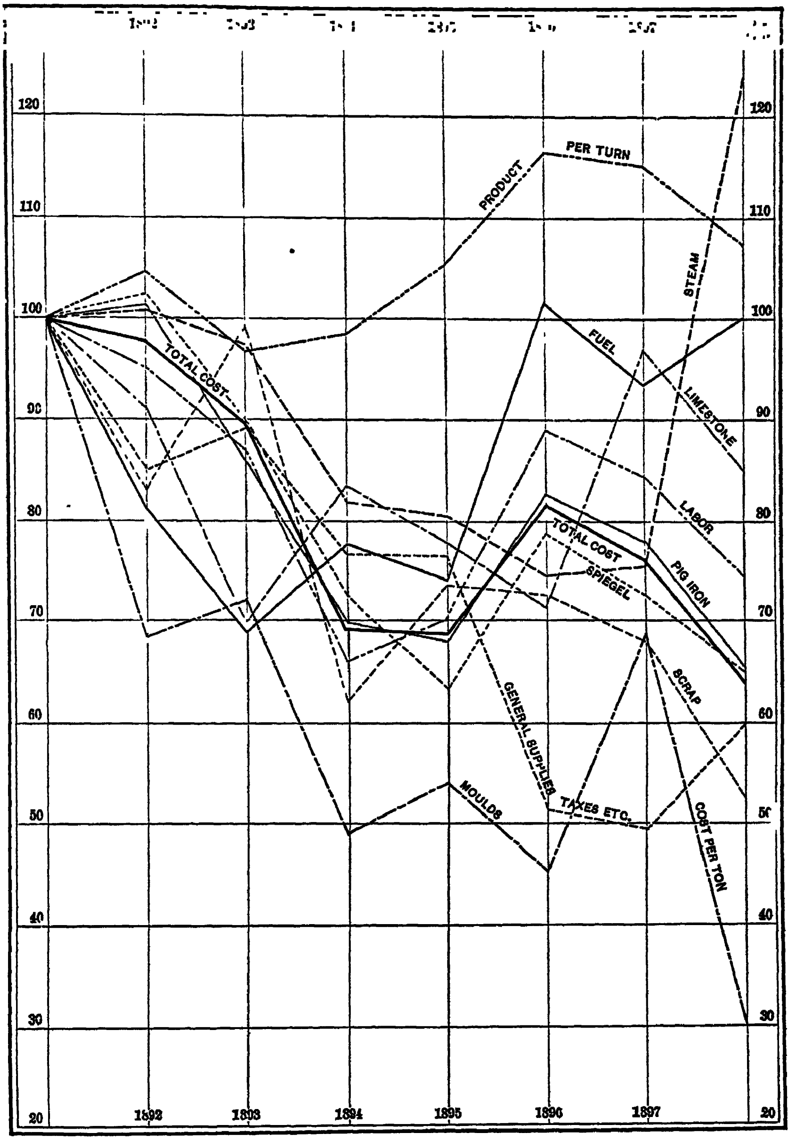


Fluctuations in Cost of Pig-Iron.—Central West.

Cost of Bessemer Ingots.

While, generally speaking, information relative to costs of producing pig-iron is quite frequently published, data bearing on the cost of converting pig into steel by the Bessemer process are not often available. One of the large Eastern steel works has furnished the figures for the following tables, the first showing the fluctuations in the cost of the principal items in producing ingots, using 1891 as the base year (See Fig. 4.):

FIG. 4.



Fluctuations in Items of Cost of Producing Ingots.

The plotting produces a rather confused diagram, but when the line of total cost is compared with the individual lines the progress in different items is more readily traced. Naturally the overwhelmingly large proportion in the cost of the materials carries the total cost line close with it. Out of the

Comparative Cost for Specified Items for Ingots, Between 1891 *and* 1898, *Both Inclusive—Base:* 100 *for Each Item in* 1891.

	1891. Single Turn.	1892. Single Turn.	1893.* Single Turn.	1894. Double Turn.	1895.† Double Turn.	1896. Double Turn.	1897.‡ Double Turn.	1898.§ Double Turn.
Pig-iron, less credit for scale and cinder	100.0000	101.2589	86.4425	70.0326	67.9603	84.6220	78.0918	65.4183
Scrap, excluding that produced	100.0000	84.1342	99.4787	62.6313	73.3790	72.4942	67.8865	52.5344
Spiegel	100.0000	102.6397	90.0522	72.6357	63.1480	78.7662	72.4856	64.7593
Limestone	100.0000	91.1398	69.9667	83.5275	77.9118	71.3810	97.1298	84.8170
Fuel	100.0000	81.3459	68.9953	77.5838	73.8717	101.3897	93.5336	100.1628
Steam	100.0000	100.9630	97.3355	81.8299	80.5457	74.5425	75.3772	124.4623
General supplies, taxes, insurance, etc.	100.0000	85.0706	89.1656	77.4463	76.3872	51.3535	49.4063	59.6652
Molds	100.0000	68.4488	72.1039	48.9880	54.1811	45.3329	67.9827	30.1931
Labor	100.0000	94.9360	86.4882	66.0190	70.0309	88.9315	84.3855	74.5680
Cost per ton	100.0000	97.6929	89.0286	69.3371	68.3455	81.3022	75.8014	64.3931
Product per turn	100.0000	104.6933	97.2465	98.4726	105.3859	116.5679	115.0105	107.2259

* September 15, 1893.—Reduction of 10 per cent. except for common labor. December 20, 1893.—General reduction of from 10 to 35 per cent.
† July 1, 1895.—General increase in wages of 10 per cent.
‡ April 1, 1897.—Readjustment of tonnage rates amounting to an average reduction of 12 per cent., common labor and wages being undisturbed.
§ Improved machinery put in operation August 1, 1898, causing delay and decreased product during three months.

whole cost, that of pig-iron, scrap, spiegel and limestone together amounted to the following percentages of the whole in the different years, the percentage of the other years being as stated:

Year.	Materials. Per Cent.	Fuel and Steam.	Molds, Supplies, Taxes, Insurance, etc.	Labor.
1891,	87.91	1.91	4.54	5.63
1892,	89.17	1.65	3.70	5.47
1893,	88.68	1.58	4.26	5.47
1894,	88.02	2.16	4.46	5.37
1895,	87.55	2.09	4.58	5.78
1896,	88.80	2.27	3.86	6.16
1897,	88.12	2.28	3.33	6.28
1898,	86.87	3.09	3.52	6.53

The participation in the cost of its different constituents is shown in the table on page 366.

The accompanying diagram shows in a broad way how the materials, the labor and the other items contribute to the cost. (See Fig. 5.)

From a large steel works in the Pittsburgh district comes the following statement showing how the cost of conversion has been reduced during the past decade:

Cost of Conversion of Bessemer Ingots, Exclusive of Raw Material.

Year.	Per Cent.
1887,	100
1888,	95
1889,	94
1890,	94
1891,	86
1892,	86
1893,	72
1894,	66
1895,	62
1896,	54
1897,	52

The cost of conversion at this plant has, therefore, been nearly cut in two in eleven years.

An effort has been made to obtain some data relating to the reduction in cost of the manufacture of open-hearth steel, but thus far without success. Few plants have been makers in this branch on a large scale for so long a period, and in the case of

Comparative Cost of Ingots Between 1891 *and* 1898, *Both Inclusive—Base:* 100 *for Total Cost Per Ton in* 1891.

	1891. Single Turn.	1892. Single Turn.	1893.* Single Turn.	1891. Double Turn.	1895.† Double Turn.	1896. Double Turn.	1897.‡ Double Turn.	1898.§ Double Turn.
Pig-iron, less credit for scale and cinder	63.5087	64.3082	54.8985	44.4768	43.1607	53.7423	49.5951	41.5463
Scrap, excluding that produced	11.9691	10.0701	11.9067	7.4964	8.7828	8.6769	8.1254	6.2879
Spiegel	12.1947	12.5166	11.9816	8.8577	7.7007	9.6053	8.8394	7.8972
Limestone	.2404	.2191	.1682	.2008	.1873	.1716	.2335	.2039
Fuel	1.5975	1.2995	1.1022	1.2394	1.1801	1.6197	1.4942	1.0001
Steam	.3115	.3145	.3032	.2549	.2509	.2322	.2348	.3877
General supplies, taxes, insurance, etc	3.0403	2.5864	2.7109	2.3546	2.3224	1.5613	1.5021	1.8140
Molds	1.5020	1 0281	1.0830	.7358	.8138	.6809	1.0211	.4535
Labor	5.6358	5.3504	4.8743	3.7207	3.9468	5.0120	4.7558	4.2025
Cost per ton	100.0000	97.6929	89.0286	69.3371	68.3455	81.3022	75.8014	64.3931
Product per turn	100.0000	104.6933	97.2465	98.4726	105.3859	116.5679	115.0105	107.2259

* September 15, 1893.—Reduction of 10 per cent. except for common labor. December 20, 1893.—General reduction from 10 to 35 per cent.

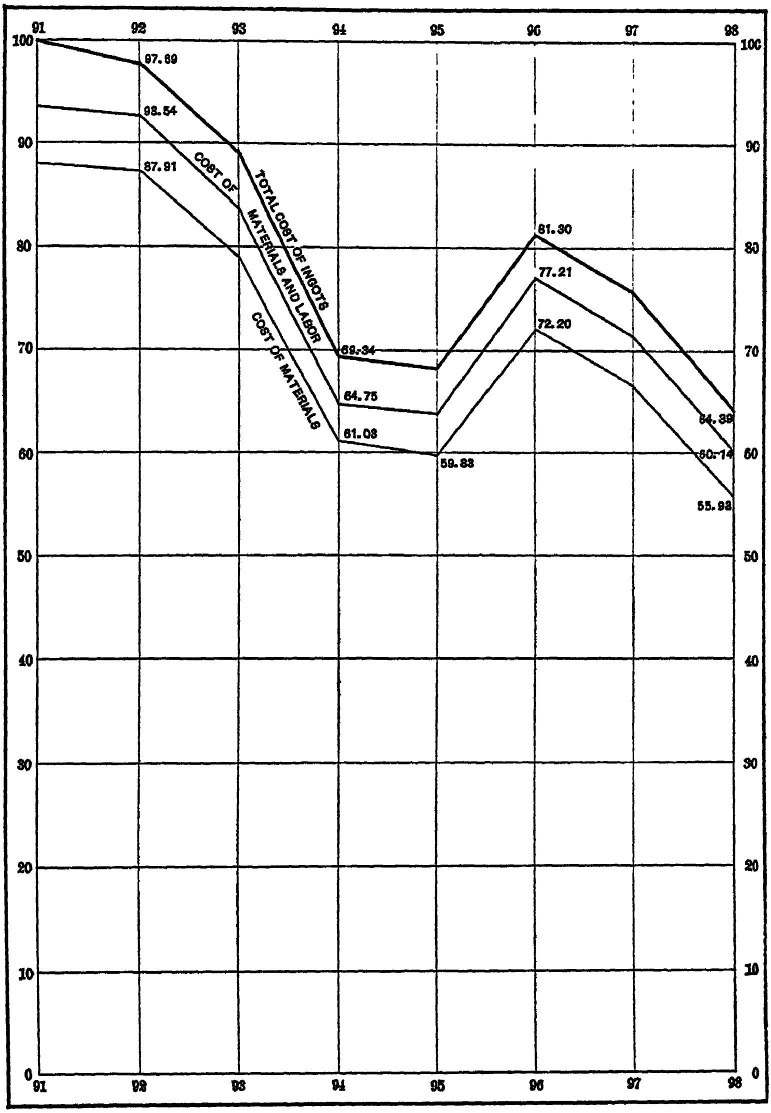
† July 1, 1895.—General increase in wages of 10 per cent.

‡ April 1, 1897.—Readjustment of tonnage rates, amounting to an average reduction of 12 per cent. in same, common labor and day wages undisturbed.

§ Improved machinery put in operation August 1, 1898, causing delay and decreased product during three months.

those who have, the majority have swung partly or wholly from acid to basic steel.

FIG. 5.

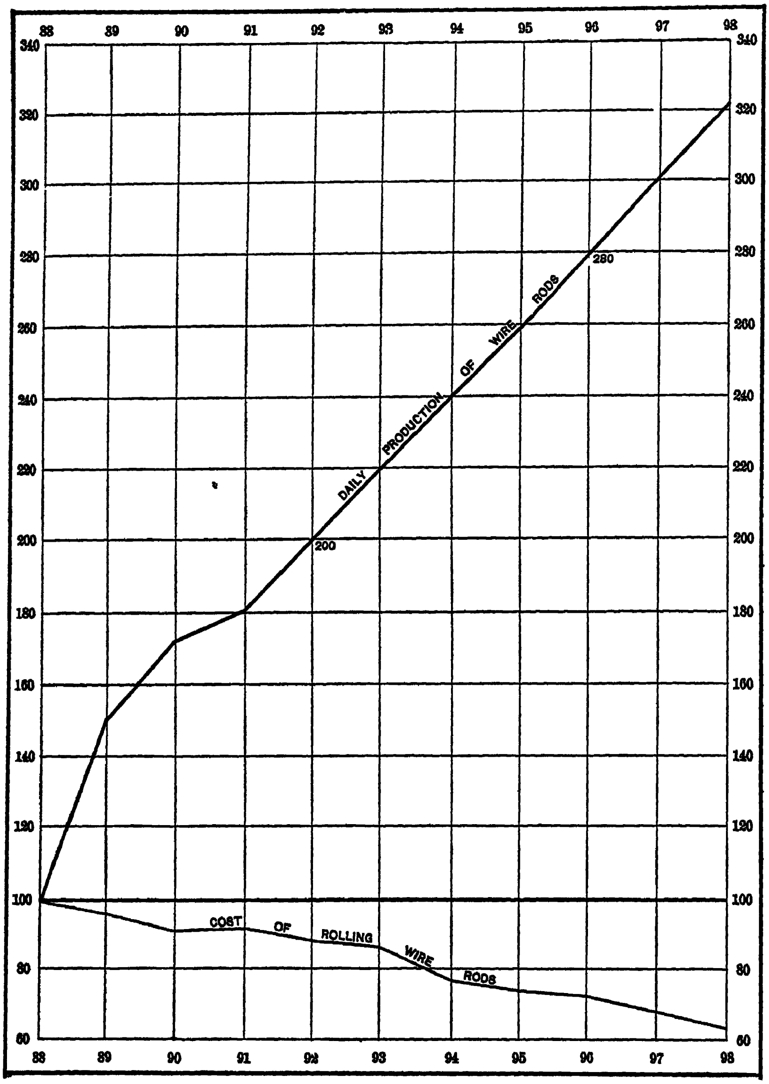


Fluctuations in Cost of Producing Bessemer Ingots.

In the case of puddling the difficulty has been even greater, since works which ten years ago produced large quantities of muck-bar have either abandoned the manufacture altogether

or are running so intermittently that no data of value are available for recent years.

FIG. 6.



Fluctuations in Cost of Rolling Wire Rods and in Output.

COST OF ROLLING RODS.

Probably in no branch of rolling-mill work has progress been so marked as in the making of wire rods, and that branch has been selected as an illustration. William Garrett, of

Cleveland, Ohio, has compiled the following record of the progressive development of the output per twenty-four hours and the cost of the conversion of the 4-inch billets into the wire rods (See Fig. 6).:

Cost of Rolling Wire-Rods.

Year.	Product Per Twenty-four Hours.	Cost of Rolling.
1888,	100	100.0
1889,	150	95.4
1890,	175	90.9
1891,	185	90.9
1892,	200	87.3
1893,	225	86.4
1894,	250	77.3
1895,	260	74.5
1896,	280	72.7
1897,	300	68.2
1898,	325	63.6

In reality the period under review only displays partially the progress made in this branch since the introduction of the Garrett mill.

Cost of Coke-Production.

Considerable as were the difficulties in obtaining data for comparison in the iron industry they were naturally very much greater in mining, because the disturbing factors are more numerous. Thus it was impossible for a large miner of coal and producer of coke to submit detailed data. In a general way, the development is indicated by the fact that, representing the cost of production of coke for the year 1887 by 100, the cost for the year 1897, figured in per cent. of the cost of 1887, was 87.3 per cent. The reductions in cost have been due to the following:

1. Improved methods in mining, by which a larger percentage of coal is recovered. By concentrating the operations a reduced cost for haulage and maintenance of mine tracks is effected.

2. Improvements in mechanical haulage appliances, like pneumatic haulage, the endless-rope system and the tail-rope system. With the introduction and extension of these there has been coupled an improvement in the character of mine

tracks by better grading, the use of heavier rails, the employment of larger ties and of better equipment generally. This has resulted in increased loads, higher speeds, and consequently a larger output at reduced cost per ton for hauling, and has more than compensated for the increased length of haul due to the retreating of the mine workings from the pit mouth.

3. Improvements due to taking advantage of gravity in hauling loaded and empty cars at the shafts, and to the introduction of automatic dumping appliances on the tipple.

4. Improvements in mine drainage by judicious concentration, by installing larger pumping appliances, and by the substitution of compressed air for steam for the purpose of draining points in the mines remote from the power plant.

5. The substitution of steam locomotives and endless gravity rope appliances for mule power for conveying the coal from the bins to the ovens and charging the latter.

6. The increased output of the coke ovens by increasing their size and by more carefully and scientifically [illegible] them.

A highly significant statement in connection with this interest is that while from 1887 to 1897 the cost fell from 100 to 87.3, the earnings of labor increased from 100 in 1887 to 112.5 in 1897.

Cost of Lead-Smelting.

What progress has been made in lead-smelting and refining is well illustrated by the following series of figures from a western plant:

Year.	Money Cost of Ore Smelted and Refined.	Fuel Consumption Per Ton of Ore Smelted.
1887,	100	100
1888,	98	97.5
1889,	97	97.1
1890,	95	95.4
1891,	93	95.2
1892,	91	92.6
1893,	88	92.1
1894,	85	91
1895,	79	85.6
1896,	74	79
1897,	65	71.2

Parallel with this improvement has gone another movement which it is somewhat difficult to express, but which neverthe-

less is one of much significance, and that is the ability to smelt successfully charges lower in lead. It has varied more in accordance with the supply of lead-ore at any particular plant than with its ability to smelt with more or less lead. Previous to 1890, 10 per cent. of lead was considered the minimum charge for satisfactory work. Since then, at the plant to which the data refer, charges as low as 6 per cent. have been used.

The reduction in cost has been due to the introduction of labor-saving appliances, and to the fact that the use of larger smelting-furnaces has required less attendance per ton of ore treated. The notable reduction in the fuel consumption is partly due to the introduction of larger furnaces and partly to improved and more intelligent methods of firing.

These examples, I believe, illustrate how rapidly, in every branch, costs have been reduced during the past decade, and they naturally lead to the question whether we may hope to continue such a rate of progress. The first impulse is to reply in the negative, since it is admittedly more difficult to effect reductions after they have once cut down costs to a certain point. Speculation is useless, but hopes are being held out that may be closer to a realization than many may be willing to admit. It is only necessary to point to the use of electric appliances in coal-mining, to the introduction into this country on a large scale of European by-product ovens, to the rapid developments lately of the slag-cement industry, to the utilization of the blast-furnace gases for power production, to the continuous open-hearth process, and to the latest achievements in rolling-mill work.

Technical knowledge is becoming more and more a common possession of all producing countries. The race is one in which one and then the other contestant is in the lead. The strain of competition is becoming more and more severe. That under such circumstances the mining engineer will not in the future crowd the records of the past it is difficult to believe. I sincerely hope that coming volumes of our *Transactions* will bear out that expectation.

Investigation of Magnetic Iron-Ores from Eastern Ontario.

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(California Meeting, October, 1899.)

General Geological Associations of the Ore-Bodies.

The protaxis of the North American continent consists, as is well known, of a large V-shaped area of Archæan rocks, which lie for the most part in the Dominion of Canada, and occupy an area of not less than 2,031,000 square miles. The western limit of this area extends from Lake Superior in a north-westerly direction to the Arctic Ocean, the southern is found along the Lower St. Lawrence as far as Labrador. A minor area, spoken of as the Adirondack region of northern New York, has a somewhat broken connection with the main body in a narrow band of igneous rock, which crosses the Upper St. Lawrence where it leaves Lake Ontario. The ancient crystallines are also presumably beneath all the later sediments, but the above brief description outlines their principal exposures.

This great rock-complex consists, for the most part, of a series of gneisses, which present great variations in both structure and composition. In certain sections areas of gneisses of the general composition of granite, and remarkably uniform in character, prevail. They consist largely, if not exclusively, of crystalline rocks in which a banding or foliation has been induced by pressure. These rocks constitute the basal member of the Laurentian system, and by later writers have been referred to as the Ottawa gneiss.

In other and quite extended areas, gneisses, regarded by many as composed of altered sediments, are associated with crystalline limestones, quartzites, and much injected igneous matter. To this series the term Grenville has been applied.

Both of these series of gneisses are penetrated by various igneous masses, of which the most important are great intrusions of several members of the gabbro family, such as anorthosites, norites, pyroxenites, and gabbros proper; the whole form-

ing the Norian series of Hunt.* These rocks are for the most part homogeneous, but in some instances exhibit that irregular structure so characteristic of gabbros—a condition brought about by a variation either in the size of the grains or in the relative proportions of the constituents from place to place.

The whole of this area is more or less productive of economic minerals, but the deposits are not uniformly distributed; some occur in a restricted region or in some special geological relations, while others may prevail over large areas and with various geological associations.

Magnetite is one of the commonest minerals, and one of the most abundant of the ores. It occurs not only as an accessory constituent in both the gneisses and gabbros, but by itself forms beds of such considerable extent and thickness that, prior to the development of the Lake Superior ranges, this region afforded a considerable supply for American furnaces. These magnetic iron-ore bodies may be classified, according to their associations, into three groups corresponding to the three series of crystalline rocks already referred to, viz.:

Ore-bodies where the magnetite occurs in lenses or as impregnations in schistose or gneissic belts. In most of these instances limestone is either altogether absent, or only occurs at some distance from the deposit.

Ore-bodies occurring in belts of crystalline limestone immediately at their contact with the harder gneissic and schistose members of the series.

Ore-bodies, titaniferous in character, occurring entirely in the anorthosites and basic gabbros.

Magnetic iron-ore bodies having the above geological associations are found in the counties of Renfrew, Lanark, Leeds, Frontenac, Hastings, Victoria, and Peterboro in Eastern Ontario. A number of these have been examined, and in the present paper some of the relations existing between their geological associations and elementary constituents are considered.

Magnetites Occurring in Gneisses and Schists.

The ore-bodies of this type exhibit a tendency to lineal arrangement, parallel with the foliation. The individual bodies may be separated by barren rock, or by rock richly impregnated

* *Chem. and Geol. Essays*, p. 279.

with disseminated magnetite. In this latter case variations in the proportion of magnetite may afford all gradations between the extremes of a magnetite-bearing rock and an ore with a small intermixture of bisilicate minerals. The different gneisses, schists, etc., associated with the ores are the more or less metamorphosed products of various igneous types, and can best be described by reference to particular occurrences.

I. *Paxton Mine.*—The Paxton mine is located on lot 5, concession 5, of Lutterworth, Victoria county. The country-rock is a reddish, granitic gneiss, containing many small amphibolite bands. The gneiss has the usual granitic elements and has suffered considerable squeezing. Hornblende and mica are very subordinate, and occasionally quartz is so predominant as to give the rock the characteristics of a quartzite. The ore-body conforms to the strike of the gneiss, but is irregular in width. In one of the main openings it is 40 feet wide. This, however, is not all iron-ore, since—as is the case with so many of the iron-ore deposits in these Laurentian rocks—the ore itself is mixed with a large proportion of various ferruginous silicates, such as hornblende, pyroxene and garnet. The garnet, which is present in considerable amount, occurs in irregular masses, no crystal forms being observed. In color it is dark reddish-brown, resembling those varieties which have been regarded as titaniferous. Chemical analysis, however, has failed to detect even a trace of titanic oxide.

II. *Seymour Mine.*—The Seymour ore-bed is situated on lot 11, concession 5, Madoc township, Hastings county. The deposit occurs in a fine-grained orthoclase gneiss. The contact between the magnetite and associated rock is for the most part formed by 15 to 18 inches of decomposing hornblende-schist, while thin belts of the same composition cut the ore-body diagonally at short irregular distances. The ore is black, fine-grained, and not only magnetic, but in some instances possesses polarity.* A large portion of the ore is solid and free alike from rock and pyritic impurities. When it is less pure, radiating green actinolite, in disseminated nodules, appears to be the principal accessory. Green and colorless fluor-spar, associated in minute pockets with calcite and quartz, is prevalent, its occurrence appearing to be related to the distribution of the

* *Report of the Bureau of Mines*, Ontario, 1892, p. 37.

hornblende-schist. Uraninite occurring in small quantities in some of the minute fissures, has been noted by Prof. Chapman.

III. *Robertsville Mine.*—This ore-body occurs on lots 3 and 4, concession 9, Palmerston township, Frontenac county. The country-rock is a typical hornblende-gneiss, containing a little feldspar, some augite, and a little secondary quartz. It is evidently either a metamorphosed diorite or diabase. The magnetite occurs in irregular masses; and although the division between the ore and the wall-rock is distinctly defined by the contrast of color, yet there is no actual separation between them, the two breaking like one rock.

Magnetites Occurring at the Contact of Crystalline Limestones with Gneisses and Schists.

These magnetite-deposits are associated with gneisses and schists of various types, which generally strike to the N. and N.E., and have an almost invariable dip to the eastward at high angles. Some of these types may be metamorphosed sediments; but the majority are undoubtedly the metamorphic product of various igneous rocks, the more basic predominating. Bands of crystalline limestone occur among these gneisses, and with them are found deposits of magnetic iron-ore. The limestones are always highly crystalline and vary from a nearly pure marble to those plentifully intermingled with various silicates—a result of the metamorphism. On account of their relatively slight resistance to pressure they have been thinned out, here and there along the strike, by squeezing. The result of this on the ore-bodies is to make them pinch and swell along the contact; and, in some instances, what undoubtedly were originally parts of the same ore-mass are now separated by considerable distances.

IV. *Black Bay Mine.*—This ore-body is located about two miles north of Calabogie, Renfrew county. The ore occurs along the contact of a metamorphosed diorite and a crystalline limestone. Disseminated through the ore, and particularly where it is in contact with the walls, there is considerable hornblende and less augite. The crystalline limestone is particularly free from bisilicates and other secondary products, but in thin sections exhibits the effects of considerable crushing. The dioritic gneiss is for the most part composed of a hornblendic

element, the feldspar being quite subordinate. Considerable augite is present; chlorite and garnet are common.

V. *Glendower Mine.*—On lot 3, concession 6, Bedford township, Frontenac county, a band of crystalline, dolomitic limestone is in contact with a coarse-grained metamorphosed pyroxenite. Near the contact, but entirely within the limestone, occurs a large bed of hard, compact magnetite, associated with much hornblende, which in former years afforded a very considerable output. For some distance from the surface the ore is quite free from sulphur. At a certain depth, however, pyrite* is found, but usually in concretionary masses, and seldom impregnating the magnetite sufficiently to detract from its value. A short distance from the main deposit the limestone is traversed by a great number of parallel bands of magnetite, so numerous and extensive as to have afforded profitable exploitation in an open cut. Intercalated between these bands of ore, serpentine occurs in both massive and fibrous forms. The limestone is coarsely crystalline, usually graphitic, and in many places is very impure because of the abundance of bisilicates, hornblende predominating. Garnet and vesuvianite crystals are also plentiful.

VI. *Dufferin Mine.*—The Dufferin mine is situated near Malone, Hastings county. The ore, which appears as a series of larger and smaller overlapping lenses, occurs in an impure crystalline limestone at some distance from its contact with a gneissic band. The lenses follow the foliation of the limestone, which is banded and contorted. The ore is considerably impregnated with hornblende and actinolite.

VII. *Howland Mine.*—This ore-body occurs on lot 26, concession 4, Snowdon township, Victoria county. The deposit follows the contact of a hornblendic-gneiss and a narrow band of limestone. The ore is fine-grained, and has associated with it much green hornblende and epidote. Near the surface it is somewhat pyritic, but with increasing depth the sulphur lessens. The gneiss presents little banding, but under the microscope the effects of considerable crushing are exhibited by the various components. The feldspar in particular is much shattered, and has afforded considerable scapolite as an alteration-product. This secondary scapolite is equally abundant with green horn-

* W. G. Miller, *Ontario Mining Institute*, Oct., 1895.

blende, the two constituting nearly the entire rock. Some mica is present, and titanite is plentiful, particularly in the immediate vicinity of the hornblende. At a distance of several hundred yards from the mine, and where the metamorphic changes are not so marked, augite is more abundant than the hornblende, and the texture is typically gabbroic.

The limestone is finely crystalline, graphitic, and often set with little scales of phlogopite. Irregularly dispersed through it are bunches of various silicates, hornblende predominating.

MAGNETITES OCCURRING IN BASIC ROCKS OF THE GABBRO TYPE.

These rocks present the usual differences found in gabbros, due to variations either in the size of the grains or the relative proportions of the constituents from place to place. They pass insensibly, by the increase or decrease of plagioclase, into anorthosites, pyroxenites, and gabbros proper. The magnetic, titaniferous ore-bodies which these igneous rocks contain do not, as a rule, have well defined walls, and may be considered as particularly basic phases of the gabbro. J. H. L. Vogt,* the eminent Norwegian geologist, has regarded similar Scandinavian deposits as excessively basic segregations of fused and cooling magmas.

VIII. *Chaffey Mine.*—The Chaffey iron-mine is situated near Newboro, in the county of Leeds. The ore, which is titaniferous, occurs in and near the margin of an extensive gabbro mass, in the form of several elongated, approximately parallel lenses. Between the gabbro wall-rock and the ore-body there is no sharply defined contact. The ore near its boundary gradually becomes leaner and leaner, finally fading away in a matrix of the country-rock. The ore, which is fine-grained, contains, besides an admixture of pyroxenic matter, a little hornblende, a few green spinels, and a small proportion of sulphur in the form of disseminated grains of pyrite.

A dark gray color characterizes the usual appearance of the gabbro, which for the most part is granitoid in texture. Near the ore-body, however, the gneissoid structure is quite marked. The plagioclase is usually subordinate to the more abundant dark silicates, consisting of augite, diallage, and original hornblende.

* Vogt, "Bildung von Erzlagerstätten," *Zeits. für praktische Geol.*, 1893.

IX. *Pine Lake Ore-Body.*—This ore-body is situated on lot 35, concession 4, of Glamorgan township, Victoria county. The containing-rock is a dark, medium-grained gabbro, which appears in the form of an elongated lens of variable width, penetrating the gneisses and schists. From place to place the rock varies greatly in the proportion of its constituents. In many instances the feldspar is more abundant than the dark silicate; but in the vicinity of the ore augite is so predominant that a thin section under the microscope exemplifies a typical pyroxenite. Reddish-brown allotriomorphic augites are seen to compose the major portion, the remainder consisting mostly of grains of amphibole, the product of uralitization. In addition there is a little titaniferous magnetite, irregular in outline, and in every instance surrounded by a rim of uralite. Accessories, such as apatite, chlorite, olivine, titanite, etc., have not been observed; the only minerals other than the bisilicates and magnetite present being a very little pyrite and a few irregular masses of kaolinized plagioclase. Near the ore-body the pyroxenite has yielded to dynamic metamorphism, as is shown by several gneissic and amphibolite bands.

The Pine Lake magnetite, similarly to that in the Chaffey mine, presents no well-defined contact with the country-rock. The whole ore-body is more or less impregnated with pyroxenic elements, and its boundaries are marked only by a gradual passage of the one into the other.

X. *Eagle Lake Mine.*—The Eagle Lake iron-mine is situated in Bedford township, Frontenac county. The ore-body occurs in and near the margin of a gabbro mass where it is in contact with the characteristic gneiss of this region. The gabbro has the typical granitic texture, with a very light-colored feldspar slightly in excess of the pyroxene and secondary hornblende. Magnetite in small corroded masses is frequent, being most abundant in the pyroxene or around its margin. No olivine has been observed, the only accessory being a few scales of biotite situated on the edge of the pyroxene. Fair exposures of the ore have been made at several places, but the beds are extremely irregular, pinching and swelling for a considerable distance, with a strike N.E. and S.W. The magnetite itself is titaniferous, perfectly homogeneous in thin sections under the microscope, and beautifully crystalline. Apatite, which occurs

associated with much of the magnetite, both in the form of grains, crystals, and large masses, causes a large proportion of the ore to be worthless. On the other hand, where macroscopic apatite fails the ore is practically free from phosphorus.

XI. Four miles north of Millbridge, Hastings county, a considerable area of gabbroic rock rises above the general level to a height of about 150 feet. The rock presents the usual variations in the relative proportions of its constituents; and in one of the particularly basic phases, due to a preponderance of augite and diallage, there is an extensive deposit of titaniferous magnetite. As is usual with iron ore-bodies found in gabbros, there is no sharp definition between the ore and the rock, the one passing into the other by inappreciable gradations. No large masses of homogeneous ore were observed, all parts of the ore-body being more or less impregnated with augite.

XII. In the township of Horton, county of Renfrew, just west of the Ottawa river, there is a considerable area of a dark gray gabbro, containing several small deposits of titaniferous magnetite. One of these is situated in the sixth range of Horton. Here the magnetite is homogeneous throughout and presents a fairly well defined boundary with the gabbro wall-rock. The gabbro is of uniform texture, the feldspar and augite being in about equal proportions. The feldspar is broadly twinned, presents the extinction-angles of anorthite, and has the dusted appearance so characteristic of the plagioclase in anorthosite.

The above completes the descriptions of the magnetic iron ore-bodies which have been taken as typical of the ore-bodies occurring in the three different geological associations to which reference has been made. On the following page are tabulated the analyses of these ores.

Method for Estimating Titanium in Titaniferous Magnetites.

The determination of titanic acid has always presented many difficulties, not only because of the tediousness of the operations, but also because of the inaccuracies of the results. When titanic acid is precipitated by boiling in a dilute sulphuric acid solution after the iron has been reduced, the results are generally low. Thus, as is well known, phosphoric acid, which is generally present in greater or less amounts, interferes

Analyses of Ores.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Fe_2O_3	41.23	61.21	57.04	56.43	55.31	51.47	63.23	46.67	39.27	62.39	37.35	29.40
FeO	26.54	30.63	24.21	29.32	27.62	28.31	26.72	22.10	21.73	26.93	28.82	29.78
Cr_2O_3	......	......	......	.08	......	......	......	.11	......	......	.12	......
MnO	1.03	.22	0.32	.23	.54	.88	.17	.23	.37	.45	.31	.22
NiO	......	......	......	......	......	......	......	.31	.27	.22	.26	.43
CoO	......	......	......	......	......	......	......	.09	.07	.05	.04	.10
Al_2O_3	6.44	1.67	0.41	1.62	.75	1.87	.21	4.45	4.61	.67	5.01	3.20
SiO_2	18.10	4.13	8.31	7.44	9.88	4.41	3.26	7.52	10.77	1.47	10.37	7.82
P_2O_5	......	.02	.03	.04	.02	.03	.01	.07	.02	.03	.09	.14
S	.05	.06	.17	.22	.16	.23	.08	.82	.11	.06	.04	.06
TiO_2	......	......	.13	......	......	......	......	10.21	13.52	6.41	8.17	17.23
V_2O_5	......	......	......	......	......	......	......	.35	.52	.23	.29	.63
MgO	2.38	.17	2.36	1 22	3.15	2.33	2.46	3.13	2.34	.33	4.23	5.67
BaO	.31	......	.14	......	.09	.41	.12	......	.07	......	......	......
CaO	2.82	.60	4.23	1.83	.43	6.51	3.73	2.17	4.84	.72	4.40	3.42
Na_2O	.42	.11	.18	.33	.11	.27	......	.52	.31	......	.57	.61
K_2O	.10	......	......	......	......	......	......	.22	.24	......	.12	.17
CO_2	.34	.09	1.50	.17	1.21	3.27	.33	......	......	......	......	......
Moisture	.79	.47	.39	.37	.54	.62	.48	.37	.44	.31	.47	.38
	100.55	99.38	99.42	99.30	99.81	100 61	100.80	99.34	99.50	100.27	100.66	99.26

with the determination by partially preventing the precipitation of titanic acid from its boiling sulphuric acid solution. There are also mechanical losses in the above method, due to the adhesion of the precipitate to the sides of the beaker, and to the finely divided condition of the precipitate.

The volumetric determination of titanic acid as described by Wells and Mitchell* appears to obviate most of the difficulties, but since titaniferous ores usually have associated with them more or less vanadium,† the results so determined are liable to error. In brief, their method is as follows: The ore is digested with hydrochloric acid, then with sulphuric; any insoluble residue is fused with potassium disulphate. The melt from the fusion is dissolved in water, added to the solution obtained from digestion, and the whole diluted to one litre. 200 c.c. of this solution is reduced with hydrogen sulphide, and, after eliminating the excess of hydrogen sulphide, is titrated with potassium permanganate. Another 200 c.c. is reduced by zinc and titrated with the same standard permanganate. In each case precautions are taken to prevent oxidation by the air. The difference between the permanganate used in the latter case and that consumed by the iron alone represents the amount corresponding to the titanic acid.

In the hydrogen sulphide reduction, in the above method, the vanadium present would be reduced to hypovanadic sulphate (V_2O_4, x SO_3), and upon titration the results for iron would be too high, since each molecule of V_2O_4 present would require as much of the standard for oxidation as two molecules of FeO. On the other hand, in the reduction of the iron and the titanium by means of zinc, the vanadium present in the original solution as vanadic sulphate (V_2O_5, x SO_3) would be reduced to hypovanadious sulphate (V_2O_2, x SO_3‡). Consequently to oxidize the vanadium from this hypovanadious condition to the vanadic, three times as much permanganate will be necessary as was required for oxidation from the hypovanadic condition to the vanadic in the titration of iron. Thus the results for both the iron and titanic oxide will always be too high, the amount of error for the latter being twice that of

* *Jour. Am. Chem. Soc.*, 17, 878. † This article, page 395.

‡ Roscoe and Schorlemmer, vol. ii., *Metals*, part ii., 1880.

the former; and since, in titaniferous ores, vanadium may be present to the extent of over one-half of one per cent. (see page 396), this cause for error is considerable.

Another method for the determination of titanic acid, which is based upon Gooch's experiments* in connection with the separation of the oxides of titanium and aluminum, is that described by Blair.† By this method quite satisfactory results may be obtained, but, as usually described, several possible sources of error and annoyance are not mentioned. In the following description of this "acetate method" some of these will be considered:

One gramme of the finely pulverized ore intimately mixed in a large platinum crucible with 12 grammes of potassium disulphate and 2 grammes of sodium fluoride is gradually heated by a low flame until the disulphate is melted. Heating is continued, keeping the mass just liquid and the temperature at the point at which slight fumes of sulphuric anhydride are given off when the lid of the crucible is raised, until all the particles of ore have disappeared.

Generally, at high temperatures, part of the sulphuric oxide liberated by decomposition of the pyrosulphate attacks the crucible, and, as a result, the removal of platinum is subsequently necessitated. By not raising the temperature higher than just intimated, contamination of the melt by platinum is either obviated or minimized. When the ore is completely decomposed, remove the flame, and, as the melt cools, incline the crucible in different directions, so that the fused mass may solidify well up on the sides. When cool, add 2 to 3 c.c. concentrated sulphuric acid, and carefully heat until the mass is just liquid. Discontinue heating, and place a platinum rod in the solidifying melt. When cold, fuse the mass where it is in contact with the crucible, and remove it by means of the platinum rod to a beaker containing 150–200 c.c. of a 5 per cent. solution of sulphuric acid. In the beaker also place the crucible and cover, and add 50 c.c. of sulphurous acid. Gently warm, but do not raise the temperature of the beaker and its contents beyond that which can be comfortably endured by the palm of the hand. The heat greatly facilitates solution, while

* *Proceedings Am. Acad. of Arts and Sciences*, 1884–85, p. 435.

† *The Chemical Analysis of Iron*, 3d edition.

the proportion of sulphuric acid present prevents precipitation of titanic acid at this temperature. Since silica has been removed by means of the sodium fluoride, the melt should completely dissolve to a clear solution. The solution is cooled and neutralized with ammonia until the precipitate which forms dissolves with difficulty. A portion of the liquid is next tested by means of hydrogen sulphide for platinum, and, if its presence is detected, the whole solution is subjected to the action of the gas until the metal is precipitated. After removing the platinum, or if no platinum is found, the solution is directly treated with 10 c.c. of sulphurous acid, 20 grammes of sodium acetate (in solution), and one-sixth the total volume of acetic acid (sp. gr. 1.04 = 49 per cent. of absolute acid). The solution is heated to boiling, the titanium being precipitated in a flocculent condition. Boiling is continued for two or three minutes. If filtered immediately, the filtrate, upon evaporation, is sometimes found to contain traces of titanic acid; this, however, may be obviated by digesting the previously boiled precipitate on the steam bath for half an hour.

* "Experiments to determine the amount of acetic acid necessary to prevent the precipitation of alumina from a boiling solution of the acetate indicate that amounts of absolute acid in excess of 5 per cent. by volume of the solution are adequate to the purpose, and that the addition of sodic acetate in reasonable amounts does not sensibly affect conditions. . . . . The small apparent losses to be observed in some of the determinations in which a large excess of acetic acid was employed are probably explicable by the tendency of the precipitate to change its consistency as the amount of free acid increases, and, in very acid solutions, to show an inclination to adhere in small amounts, but quite persistently, to the vessel in which the precipitation takes place."

After allowing the precipitated titanic acid to settle, filter, wash with hot water containing 5 per cent. of acetic acid, and finally with hot water. The washed precipitate, after drying, instead of being white, is generally dark-colored, and is always more or less contaminated with various impurities, as iron, alkali sulphates, alumina, phosphoric acid, vanadic acid, etc. By some it is thought that the small quantity of iron present in the precipitate is carried down in the ferrous condition. It is also possible that during the filtering a little of the iron becomes oxidized and is precipitated as basic acetate. As referred

* Gooch, *Proceedings Am. Acad. of Arts and Sciences*, 1884–85, pp. 441 and 439.

to by Gooch,* titanic hydrate, like aluminum hydrate, has a tendency to occlude the sulphates of the alkalies, the amount carried down by the former in most instances being quite considerable. As is well known, alumina or phosphoric acid, if present in the original sample, will be found in small quantities in the precipitate. On page 388 of this article it is demonstrated that vanadic acid is also partially precipitated with the titanic acid. In order to eliminate these impurities from the titanic oxide, the precipitate is fused with sodium carbonate (avoid presence of potassium carbonate) and a little sodium nitrate, in order to obtain a soluble phosphate, vanadate, and aluminate of sodium; the titanium, at the same time, is converted into insoluble sodium titanate, and the iron into insoluble ferric oxide. A liberal amount of the flux and an hour's fusion with the strong flame of a blast-lamp are necessary to effect these changes completely. After fusion, the melt is boiled with a solution of sodium carbonate, filtered, and washed with water containing a little sodium carbonate. The insoluble sodium titanate and ferric oxide are collected on a filter, dried in an air-bath, and transferred to a platinum crucible. The filter-paper is burned on a platinum wire, and the residue also added to the crucible. The contents of the crucible are fused with a little sodium carbonate, and the cooled mass treated in the crucible with sulphuric acid, heat being gradually applied until fumes of sulphuric anhydride are evolved. After cooling, the liquid or pasty mass is dissolved in a mixture of 100 c.c. water and 20 c.c. sulphurous acid. Then, after neutralizing with ammonia until the precipitated titanic acid dissolves with difficulty, 5 to 8 grammes of sodium acetate (in solution) and 25 c.c. of acetic acid (sp. gr. 1.04) are added. The solution is boiled for several minutes; digested on the steam-bath for half an hour at a temperature just below boiling; the precipitated titanic hydrate filtered; washed with hot water containing 5 per cent. of acetic acid, and finally with hot water; ignited and weighed as titanic oxide (TiO_2).

Method for Estimating Vanadium in Titaniferous Magnetites.

Ten grammes of the finely pulverized ore are thoroughly mixed with 50 grammes of sodium carbonate and 6 grammes.

* Gooch, *Proceedings Am. Acad. of Arts and Sciences*, new series, vol. xii., p. 441.

of sodium nitrate. The mixture is added in small quantities to a platinum crucible, each addition being thoroughly fused before the next is added. In this way the infusible ferric oxide is scattered throughout the melt instead of being agglomerated in a single large mass, which happens if the whole mixture is fused at one time. After all is added and fused, the whole mass is subjected for an hour to the highest temperature which it is possible to obtain from two blast-lamps. The melt is digested in boiling water until the carbonates, etc., are dissolved, and the ferric oxide thoroughly disintegrated. A second fusion of the residue is found to be necessary in order to separate all the vanadium. After combining the aqueous extracts, alcohol is added to reduce the manganese, after which the greater part of the alkali is neutralized with perfectly colorless nitric acid, the solution yet remaining slightly alkaline. Free carbon dioxide is eliminated by boiling, care being taken to keep the solution alkaline. During the neutralization and subsequent boiling the bulk of the alumina and silica is precipitated. Filter, and to the filtrate add nitric acid, drop by drop, until just acid. The solution is again rendered slightly alkaline by the addition of a few drops of sodium carbonate, boiled for a few minutes, and again filtered. To the filtrate, still slightly alkaline, barium nitrate is added. The precipitate, consisting of barium vanadate and barium carbonate (also barium chromate, phosphate, etc., if these elements are present), is collected on a filter-paper, and the filter-paper with its contents is removed to a beaker and digested with dilute sulphuric acid for some time. After filtering, the solution which contains the vanadium as vanadic acid is concentrated to about 100 c.c. The solution is rendered alkaline with 2 or 3 c.c. of ammonia; heated to boiling for a few minutes to facilitate the conversion of the vanadic acid into ammonium metavanadate; solid ammonium chloride is added until it dissolves with difficulty, and this is followed by 200 c.c. of a mixture of alcohol and ether (1 : 1). The ammonium metavanadate almost immediately begins to crystallize out, and after standing three or four hours in a cool place, may be filtered. The precipitate is first washed with a strong solution of ammonium chloride which has been rendered alkaline with ammonia and which contains alcohol. A final washing is made with the mixture of alcohol and ether.

The dried precipitate is ignited in a porcelain crucible, two or three drops of nitric acid added, re-ignited and weighed. Since, however, the titaniferous ores may contain small amounts of chromium and phosphorus, traces of the oxides of these elements may contaminate the vanadic oxide.* In order to obviate this probable error the vanadic oxide thus obtained is dissolved in sulphuric acid (1 : 1) and reduced by SO_2 after diluting. The sulphurous acid converts V_2O_5, x SO_3 into V_2O_4, x SO_3, which is perfectly unchanged in acid liquors, so that the excess of SO_2 can be removed by boiling in a current of carbon dioxide without danger of oxidation. After elimination of the sulphurous acid the solution, which should now have a volume of about 50 to 100 c.c., is titrated at a temperature of about 70–80° C. with a $^N/_{100}$ solution of potassium permanganate. As shown by Hillebrand,† at temperatures near boiling, chromium, if present, is oxidized, thus making the vanadium result too high. The phosphoric acid almost invariably present in smaller or larger amounts does not affect the result.

The coloration obtained by the permanganate generally disappears after a short time, but is reproduced by the addition of another drop. In every case the first appearance of the pink color is the indication that all the vanadium is oxidized. In solutions at a temperature near boiling (chromium absent) the first appearance of pink is permanent.

"One or two checks are always to be made by reducing again in a current of sulphur dioxide gas, boiling this out in a current of carbon dioxide again, and repeating the titration."‡

PREPARATION OF PURE VANADIC OXIDE.

Before proceeding with the precipitations of vanadium, subsequently described, it was found necessary to prepare pure vanadic oxide, since the various samples of vanadic acid and ammonium metavanadate at my disposal were found to leave an insoluble residue after digestion with hydrochloric or sul-

* Tungsten and molybdenum, if present in the ore, would also be found in the ignited vanadic oxide. In the ores examined neither could be detected. Recently W. F. Hillebrand (*Am. Jour. of Sci.*, Sept., 1898, p. 209) has shown that molybdenum occurs in traces in many acidic rocks, but appears to be absent from basic types, such as gabbros.

† *Am. Jour. of Sci.*, Sept., 1898, p. 214.

‡ *Ibid.*, p. 215.

phuric acid. Since in their occurrence the various minerals of vanadium, from which vanadic oxide of commerce is prepared, may have associated with them minerals containing tungsten, arsenic, copper, lead, bismuth, zinc, chromium, and phosphorus, these elements were particularly suspected as impurities.

Ammonium metavanadate (marked C. P.) was taken and eliminated from such of these elements as were present as follows: 100 grammes of the salt were dissolved in hot dilute sulphuric acid (water one part, acid two parts), an insoluble residue remaining. After cooling, diluting and filtering, the residue was found to consist of barium sulphate and a little silica. Tungsten if present would have been precipitated as yellow WO_3,*† insoluble in hot sulphuric acid. The filtrate, after partially neutralizing with ammonia, was reduced with sulphurous acid and treated with a current of hydrogen sulphide. There was no precipitate, showing the absence of arsenic, copper, molybdenum,‡ and bismuth. A portion of the solution was then made alkaline with ammonia, and the passage of hydrogen sulphide continued through it without the formation of any precipitate, indicating the absence of iron, alumina, titanic acid, zinc, etc. The other part of the solution, after the hydrogen sulphide was removed by boiling, aided by a current of carbon dioxide, was cooled and a portion tested§ for phosphoric acid, after neutralizing with ammonia, by adding ammonium nitrate, a little nitric acid, and finally molybdic solution. No phosphorus was detected. The remainder of the solution was oxidized by potassium chlorate, then made strongly alkaline with ammonia and heated. Excess of pure ammonium chloride was added and the whole allowed to cool. The precipitated ammonium metavanadate was filtered and washed with a strong ammonium chloride solution until washings ceased to give a reaction for sulphuric acid. After drying in an air-bath at 110° C. the crystalline vanadate was transferred to a porcelain dish and heated in a gas muffle for two hours, the inside of the muffle being at a dull red heat.

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* Desi, *Jour. Am. Chem. Soc.*, 19, 213.

† Dammer, *Handbuch der anorganischen Chemie, vol. iii.*, 706.

‡ *Zeitschrift für Analyt. Chemie*, 35, 77–86.

§ Holverscheit, *Chem. Central-Blatt*, 1890, 1, 977.

Testing Purity of the Vanadic Oxide.—Different amounts were heated in a porcelain crucible until fused. In each case the resulting steel-gray crystalline mass was found to weigh exactly the same as the amount of vanadic oxide taken, indicating the absence of moisture and ammonia.

Further, different amounts were dissolved in sulphuric acid, reduced by a current of sulphur dioxide, and the excess of sulphur dioxide removed by boiling with carbonic acid. The solution was diluted with hot water and titrated with a standard potassium permanganate solution. The number of cubic centimetres of permanganate consumed was in each instance found to be the same as the calculated theoretical quantities. These results showed the vanadic oxide to consist of V_2O_5, and not a mixture of V_2O_4 and V_2O_5 as is claimed by many.*

PRECIPITATION OF VANADIUM WITH TITANIUM IN THE "ACETATE METHOD."

In the ordinary methods described for the estimation of the various constituents of iron-ores the probable occurrence of vanadium is occasionally referred to, but no intimation is given as to where it may be identified in the usual schemes of analysis, or whether its presence will interfere with the correct determination of other elements. Recently W. F. Hillebrand† has pointed out that

> "In the regular course of analysis vanadium will be weighed with alumina, iron, titanium, etc., since it is precipitated by both ammonia and sodium acetate in the presence of those and other metals; hence the alumina percentages in nearly all rock analyses heretofore made are subject to correction for the vanadium the rock may have held. . . . All determinations of iron are likewise affected by its presence."

In the analysis of the titaniferous ores vanadium was found contaminating the titanic acid precipitate obtained in estimating titanium according to the "acetate method" described by Blair,‡ and referred to on page 382 of this paper. In order to ascertain if vanadium is carried down with the tita-

* Read, *Jour. of the Chem. Soc.*, 65, 313; Poggendorff's *Annalen der Physik und Chemie*, 22, 1; Watts's *Dictionary of Chemistry*, vol. iv., 849; *Jour. Amer. Chem. Soc.*, xx., No. 6, June, 1898.

† *Am. Jour. of Science*, Sept., 1898, p. 212, footnote.

‡ *The Chemical Analysis of Iron*, p. 178.

nium completely or according to some ratio, vanadic oxide and titanic oxide were mixed in different proportions and fused with potassium disulphate. To the melt 2–3 c.c. of concentrated sulphuric acid was added. After re-fusing and cooling, the cake was dissolved in 150 c.c. of water, the operation being hastened by gently warming. The solution was cooled, and after diluting, the usual traces of platinum (from the crucible) were precipitated by hydrogen sulphide. The filtrate was partly neutralized with ammonia until the precipitated titanic hydrate redissolved with difficulty. To the solution were then added 50 c.c. of strong sulphurous acid, 20 grammes of sodium acetate (in solution), and one-sixth the total volume of acetic acid (sp. gr. 1.04). The temperature was raised to boiling and continued for several minutes. After digesting on the steam-bath for half an hour the precipitated titanic acid was filtered, washed with dilute acetic acid, dried, ignited and weighed. The following are the results:

Grammes of TiO_2 Taken.		Grammes of V_2O_5 Taken.	Molecular Ratio.	Weight of TiO_2 Precipitate.
I.	A .4000	.9136	1:1	.4129
	B .4000	.9136	1:1	.4111
II.	A .4000	.2316	4:1	.4071
	B .4000	.2316	4:1	.4092
III.	A .4000	.0579	16:1	.4047
	B .4000	.0579	16:1	.4060
IV.	A .4000	.0145	64:1	.4038
	B .4000	.0145	64:1	.4019

From the foregoing results it is to be observed that the vanadium is only partially precipitated, that the amount carried down by the titanic acid depends somewhat upon the relative proportions of titanic oxide and vanadic oxide present, and that there does not appear to be any definite ratio between the amount of vanadium present and the quantity precipitated. The discrepancies in the results obtained, even when the same quantities were used, suggested a variation due to the slight differences of conditions. Accordingly Experiment II. was repeated under the following conditions. In the first instance the amount of free acetic acid was restricted to about one-twentieth the total volume, while in another it equaled half the volume. In the first case the amount of titanic acid ob-

tained weighed 0.4141 gramme, and in the latter, 0.4033 gramme, showing that the amount of vanadium precipitated depends upon the amount of free acetic acid, being less when the acid is present in great excess.

Precipitation of Vanadium in the Presence of Iron.

(*a*) By Ammonia.

As previously remarked, Hillebrand has intimated that vanadium will appear in the ammonia precipitate of iron. He has also shown how in the dissolved precipitate the two may be estimated volumetrically, by means of a standard solution of potassium permanganate, the combined result being expressed in terms of iron. From this combined result the previously estimated proportion of the vanadium can be deducted, leaving the correct iron value of the sample. Having ascertained, however, that the precipitation of the vanadium with the iron is not always complete, the following experiments were made in order to determine the conditions under which it is wholly precipitated.

Experiment I.—To 0.3000 gramme of ferric oxide in a hydrochloric acid solution, was added 0.0855 gramme of vanadic oxide (molecular ratio 4 : 1). The solution was heated and a little potassium chlorate added. After again heating, ammonia was added in slight excess beyond that required for precipitation, and the whole boiled for several minutes. The filtrate contained free ammonia, and when tested gave strong reactions for both iron and vanadium. The precipitate was washed with both cold and hot ammonia water of various strengths. In each case the washings gave reactions for iron and vanadium, the quantity present being greater the stronger the ammonia solution used. Washed with hot or cold distilled water the washings were likewise found to contain iron and vanadium. The addition of a little ammonium chloride to the wash-water, however, prevented this removal of iron and vanadium from the precipitate. On the other hand, ammonium chloride wash-water containing free ammonia was found to remove both iron and vanadium from the precipitate.

Experiment II.—The same course was followed as in Experiment I. except that boiling was continued until ammonia ceased to be evolved. The filtrate gave no reaction for iron or

vanadium. The precipitate was washed with water containing a little ammonium chloride, and then dissolved in as little hydrochloric acid as possible. Hydrochloric acid was used to dissolve the precipitate rather than sulphuric, since, in the subsequent reduction by SO_2, it was found impossible in a sulphuric acid solution to reduce all the ferric iron. The dissolved precipitate was nearly neutralized with ammonia; reduced by SO_2 (the excess of SO_2 being removed); diluted with boiling water to about 500 c.c., and, after the addition of 5–7 c.c. of "preventive solution"* titrated with standard permanganate, 24.6 c.c. being consumed. Separately the quantity of iron taken required 19.7 c.c. and the vanadium 4.9 c.c. of the standard, the two quantities combined, or 24.6 c.c., being the same as that required by the precipitate.

This experiment was repeated several times, and in each case the results obtained were approximately the same as the calculated.

Experiment III.—To 0.3000 gramme of ferric oxide in a hydrochloric acid solution was added 0.0855 gramme of vanadic oxide which had been reduced by SO_2. The solution was heated to boiling and ammonia added, the precipitate appearing black, probably due to the presence of vanadyl oxide. Boiling was continued until ammonia ceased to be evolved. The filtrate when tested showed the presence of a very considerable amount of vanadium, but did not give a reaction for iron.

From the foregoing experiments it is to be observed that for the complete precipitation of vanadium in the presence of iron by ammonia, free ammonia must be eliminated before filtering, and that the vanadium should be present in the vanadic and not in the hypovanadic condition. Since, however, the agencies which oxidize the iron will oxidize the vanadium, loss of the latter element because of a low state of oxidation is highly improbable in the ordinary course of analysis.

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* The name "preventive solution" has been used by Dr. E. H. Miller (*Notes on Quantitative Analysis for Electrical Engineers*, p. 19) instead of the confusing term "titrating solution" for the solution used to obviate the errors due to chlorine when titrations are made with potassium permanganate in a hydrochloric acid solution.

The solution is made by dissolving 160 grammes of manganese sulphate in 1750 c.c. of water, then adding 330 c.c. of phosphoric acid, 1.7 sp. gr., and 320 c.c. of concentrated sulphuric acid, 1.82 sp. gr.

Further, since by itself iron is completely precipitated by ammonia, it may be inferred that it is some compound of iron and vanadium (probably a ferric vanadate) soluble in ammonia, which carries a part of the former into the filtrate in the presence of free ammonia. That the two are chemically combined in the precipitate is also suggested by the fact that if vanadium were precipitated by the ammonia as ammonium metavanadate, considerable of the vanadium would remain in solution, as the metavanadate would be quite soluble under the conditions of temperature and dilution maintained in the experiments.

(*b*) In Basic Acetate Precipitation.

To a hydrochloric acid solution containing 0.3000 gramme of ferric oxide and 0.0855 gramme of vanadic oxide a little potassium chlorate was added and the solution boiled. After cooling, the solution was carefully neutralized with sodium carbonate solution until a drop of the diluted carbonate solution gave a slight permanent precipitate. The precipitate was dissolved by a drop of dilute hydrochloric acid. After diluting to 800 c.c., 10 grammes of sodium acetate (in solution) were added, and the solution heated to boiling, boiling being continued for one minute. After filtering, neither iron nor vanadium could be detected in the filtrate. The precipitate was washed with dilute ammonium chloride, dried, ignited, dissolved in hydrochloric acid, reduced (by SO_2), and finally titrated with potassium permanganate, using the "preventive solution." The following results were obtained:

	C.c. of $KMnO_4$ Calculated.	C.c. of $KMnO_4$ Required.
(1), ...	24.6	24.62
(2), ...	24.6	24.57
(3), ...	24.6	24.60

From these results it is to be observed that when the ordinary conditions are followed the precipitation of vanadium with iron in the basic acetate precipitation is complete.

(*c*) By Ammonium Succinate.

The same quantities of ferric oxide and vanadic oxide were used as in the basic acetate precipitations referred to above. Oxidation and neutralization were also similarly effected.

Experiment I.—The neutral solution of the mixed oxides was diluted to 300 c.c., ammonium succinate added, and the

precipitate, which immediately formed, was filtered without warming. The filtrate was found to contain a considerable quantity of both iron and vanadium. When the precipitate was washed with hot or cold water, the washings were found to give reactions for both vanadium and iron; but when a dilute solution of ammonium chloride was used, neither could be detected.

Experiment II.—Repeated Experiment I., and, in addition, heated to boiling, and boiled for two minutes before filtering. The filtrate gave strong reactions for iron and vanadium.

Experiment III.—Repeated Experiment II., but in this instance boiling was continued for ten minutes. Iron or vanadium could not be detected in the filtrate. The precipitate was washed with ammonium chloride, dried, ignited, dissolved in hydrochloric acid, and, after reduction (with SO_2), titrated with potassium permanganate, using the "preventive solution." The following results were obtained:

	C.c. of $KMnO_4$ Calculated.	C.c. of $KMnO_4$ Required.
(1), ...	24.6	24.60
(2), ...	24.6	24.60
(3), ...	24.6	24.58

Experiment IV.—In this instance the volume was restricted to 100 c.c.; otherwise, the same conditions were followed as in Experiment III. The filtrate was found to contain a very considerable proportion of both iron and vanadium.

From the above results it is to be observed that vanadium is completely precipitated with iron by ammonium succinate under the following conditions. After careful neutralization, the solution must be diluted so that its volume is about 750 c.c. for every gramme of the mixed oxides present; the precipitate should be boiled eight to ten minutes; the wash-water should contain a little ammonium chloride.

(*d*) By Sodium Benzoate.

Using sodium benzoate as a precipitant instead of ammonium succinate, the experiments, as described under (*c*), were repeated, and with approximately the same results.

(*e*) By Caustic Potash.

Experiment I.—A hydrochloric acid solution containing 0.3000 gramme of ferric oxide and 0.0855 gramme of vanadic

oxide (molecular proportions 4 : 1) was neutralized until slightly acid. One or two grammes of potassium chlorate were added, and the solution boiled for a few minutes. After cooling, caustic potash solution was added in slight excess of that required to effect complete precipitation. Without warming, the solution was filtered. The filtrate gave strong reactions for both iron and vanadium.

Experiment II.—The quantities of ferric oxide and vanadic oxide used, also the preliminary conditions, were the same as in Experiment I. The solution, however, was heated to boiling before the addition of the caustic potash, which was added in considerable excess. After precipitation, boiling was continued for two or three minutes. The filtrate gave strong reactions for iron and vanadium.

Experiment III.—Repeated Experiment II., using a large excess of caustic potash, and boiled vigorously for one hour. The filtrate contained both iron and vanadium in large quantities.

From the foregoing experiments it is to be noted that vanadium is not completely precipitated with iron by caustic potash, the ferric vanadate (?) being soluble in excess of the precipitant. It is also to be observed that the separation of vanadium as soluble alkaline vanadate from iron cannot be effected by boiling the two in a strong alkaline solution.

Precipitation of Vanadium in the Presence of Aluminum—By Ammonia.

Experiment I.—0.1913 gramme of alumina and 0.0855 gramme of vanadic oxide (molecular ratio, 4 : 1) were brought together in a hydrochloric acid solution and boiled. After cooling, ammonia was added in slight excess of that required for complete precipitation. The reddish-yellow precipitate was found to contain both vanadium and aluminum, while the filtrate, which retained the reddish-yellow tint characteristic of free vanadic acid, was also found to contain both of these elements.

Experiment II.—Quantities and conditions the same as in Experiment I.; but instead of working in the cold the solution was brought to boiling. Just before coming to a boil the reddish-yellow color of both the precipitate and the solution began

to disappear. After a few minutes' boiling the precipitate became white, and the solution, which still contained free ammonia, became colorless. After filtration, both the precipitate and the solution were found to contain vanadium, the major portion being in the latter.

Experiment III.—Quantities and conditions similar to Experiments I. and II. The solution was boiled until all the free ammonia was expelled. Just as the last traces of ammonia were being eliminated, both the solution and the precipitate began to assume a faint yellowish tinge, which intensified, with prolonged boiling, to a deep reddish-yellow. Boiling was continued for half an hour, the color still remaining. After filtration, the solution was found to contain nearly all of the vanadium and traces of alumina. On the other hand, the precipitate was found to contain nearly all the alumina and also a small quantity of vanadium; the latter could not be removed by washing twenty-five times with boiling water.

From these experiments it is to be observed that vanadium is only partially precipitated by ammonia in the presence of aluminum, and also that the precipitation of aluminum is incomplete in the presence of vanadic oxide. In this respect the influence of aluminum differs from that of iron, since, in the presence of the latter, as has been shown, vanadium, as well as the iron, can be completely precipitated by ammonia.

Occurrence of Vanadium in Titaniferous Magnetites.

In review of the analyses (p. 380) of the magnetic iron ores previously described, it may be noted that vanadium invariably appears as a constituent of those ores which are titaniferous. A number of non-titaniferous ores besides those described were examined for this element, but in no instance was it detected. The first few examinations of the non-titaniferous ores, however, yielded traces of vanadium, but in unappreciable amounts.

In the *Journal of the Franklin Institute* (November 19, 1889) Professor E. F. Smith reports the occurrence of vanadium in caustic potash. Donath* also reports finding as much as 0.16 per cent. of vanadic oxide in a sample of commercial

* Dingler's *Polytechnisches Journal*, 240, 318.

caustic soda. These facts suggested that the constant trace of vanadium, which the non-titaniferous ores yielded, might be due to its occurrence in the carbonate used in the fusion rather than in the ore itself. Accordingly a blank analysis was made, using the same amount of alkali carbonate as before. The same trace of vanadium was obtained. This trace, when dissolved and treated in alkali solution with hydrogen sulphide, gave approximately the same intensity of ammonium sulpho-vanadate coloration as had been obtained from the treatment of the ore.

That vanadium is an invariable constituent of titaniferous minerals, as rutile, brookite, anatase, titanite, etc., has frequently been noted. From the analyses (p. 380), however, it is to be observed that an approximate ratio appears to exist between the percentage of titanic oxide and vanadic oxide present in these titaniferous ores, thus:

Number of Ore.	Percentage of TiO_2.	Percentage of V_2O_5.	Ratio of TiO_2 to V_2O_5.
VIII	10.21	.35	29 : 1
IX	13.52	.52	26 : 1
X	6.41	.23	28 : 1
XI	8.17	.29	28 : 1
XII	17.23	.63	27 : 1

The following analyses of five Adirondack titaniferous magnetites, made by the U. S. Geol. Survey for Prof. J. F. Kemp (to whom I am indebted for their presentation), appear to corroborate this ratio:

	Percentage of TiO_2.	Percentage of V_2O_5.	Ratio of TiO_2 to V_2O_5.
1	18.82	.62	30 : 1
2	13.07	.50	26 : 1
3	10.55	.34	31 : 1
4	16.45	.61	27 : 1
5	15.66	.55	28 : 1

From the foregoing analyses it appears that in the titaniferous magnetites, vanadic and titanic oxides follow a ratio approximating 1 : 28. From the regularity manifested in the

proportion of vanadium to titanium it is possible that in the titaniferous ores these two elements are related to each other in a manner analogous to that existing in the complex inorganic acids which have been studied by Gibbs, Marignac, and others.

In these complex inorganic acids we find one oxide related to another in a definite ratio, regular series following with gradations in content of one of the acidic oxides to the other; for example, in the phosphomolybdic acids the ratio of P_2O_5 to MoO_3 varies in different compounds from 1:10 to 1:48. In some of these acids, ratios of 10, 32, 36, 44 and 48 molecules of MoO_3 to one of P_2O_5 seem to constitute acids which are more or less definite. That titanium is capable of combining with other acidic oxides to form complex inorganic acids is shown by the phosphotitanates. On the other hand, Gibbs has shown "that V_2O_5 may form combinations with a number of molecules of tungstic or molybdic teroxide analogous to phosphotungstates, or phosphomolybdates." Thus from our knowledge of the complex inorganic acids and from the proportion of V_2O_5 to TiO_2 in these ores, it would seem that a complex inorganic acid containing vanadic and titanic oxides (vanadotitanate), in which the ratio approximates 1:28, exists in these titaniferous magnetites. Or it may be possible that a complex inorganic acid containing a less amount of titanic oxide than that expressed in the ratio of 1:28 exists, and that the additional titanic oxide, indicated by analyses, occurs combined with iron as iron titanate.

Occurrence of Nickel and Cobalt in Titaniferous Magnetites.

Of the magnetites examined it has been found that nickel and cobalt are universal constituents of those ores which are titaniferous, while the non-titaniferous magnetites of the region have not, so far as examined, been found to contain any. Both metals are always present, the nickel invariably greatly in excess of the cobalt, but apparently with no relation.

In addition to the magnetites previously described, the following titaniferous ores were subjected to partial analyses and yielded the following results:

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Metallic Ni and Co, .	.39	.27	.32	.68	.11	.17	.08	.10
TiO_2, . . .	12.01	9.70	18.30	7.70	8.60	—	—	—
Metallic Fe, . .	58.20	61.20	56.40	64.20	—	—	—	—
S, ...	0.13	.08	.1	.14	—	—	—	—

Localities.—I. Newfoundland. II. North shore of Lake Superior. III. Minnesota. IV. Glamorgan, Victoria county. V. Ivigtut,* Norway. VI., VII., VIII. Adirondacks, N. Y.

From these analyses it may be inferred that the occurrence of nickel and cobalt in titaniferous magnetites is general and not peculiar to the ores of the region particularly discussed.

The presence of nickel in an ore rich in titanium has been recorded in the analysis of the titaniferous magnetite of Cumberland, R. I. This deposit occurs in a peridotite, and by some the nickel has been regarded as being combined in the olivine. The gabbros, pyroxenites, etc., in which the ores already referred to occur, are olivine free and without evidence of its alteration products. Hence, in these instances, we cannot regard the nickel as isomorphous with iron in olivine.

Further, in its most abundant American occurrence nickel is found as a constituent of pyrrhotite, and in this association is believed to exist as a sulphide. Review of the analyses, however, shows us that the titaniferous magnetites are very low in sulphur, and in several cases the total sulphur present is insufficient, on the basis of a sulphide combination, to account for even the small percentage of nickel present. In these instances, then, we must look for a different combination for at least a part, if not all, of the nickel. Since, however, nickel in many of its combinations affords compounds analogous with those of zinc, iron, etc., we might assume that in these ores it occurs as an oxide.

Cutting the limestones, gneisses, and gabbros, over the area under consideration, we find a great abundance of dikes. Many observers, as Sir Wm. Logan, Vennor, Prof. Harrington, and others, have noted their occurrence, and many have been described. Recently† Prof. W. G. Miller and R. W. Brock, School of Mining, Kingston, referring to a basic dike located along the Rideau canal, have drawn attention to the fact that it contains nickel. Acting upon this suggestion, a number of

* Purchased sample.

† *Canadian Record of Science*, Oct., 1895.

dikes from Eastern Ontario, together with several from the Adirondack region, N. Y., have been examined for nickel, the results being as follows:

	I.	II.	III. Per Cent.	IV.	V.	VI.	VII. Per Cent.	VIII. Per Cent.	IX. Per Cent.
Ni and Co,	trace.	trace.	.09	none.	none.	trace.	.07	.73	.51

I. From Bedford township, Frontenac county. This dike is evidently an altered diabase. The bisilicate is a secondary hornblende. A few irregular masses of magnetite are present, but no olivine was observed.

II. From Adam's bay along the Rideau canal. In thin sections it presents the characteristics of a diorite. A little magnetite is present, but no olivine.

III. From Dungannon, Hastings county. Typical diabase. No olivine is present.

IV. From Dungannon, Hastings county. A diorite.

V. From near Jay, Essex county, N. Y. A camptonite.

VI. From Clinton county, N. Y. A typical diabase containing a little olivine.

VII. From Franklin county, N. Y. An olivine diabase.

VIII. From Lutterworth, Victoria county. This dike is an olivine free diabase containing a little hypersthene and considerable magnetite in irregular grains.

IX. From Snowdon, Victoria county. The same as VIII.

From the analyses we observe that only two of the dikes examined carry more than a trace of nickel and cobalt. These two dikes are olivine free, while others containing this bisilicate have only traces of the two metals. These facts corroborate the previous opinion that nickel (also cobalt) is present in these titaniferous ores, in a combination other than that of olivine.

Examined in thin sections, these two dikes present no characteristics distinguishing them from the diabase dikes containing only traces of nickel and cobalt, other than a slightly greater proportion of magnetite. In order to ascertain if the nickel and cobalt in these two dikes are intimately associated with the magnetite, 600 grammes of the Lutterworth dike (crushed so as to pass through a 40-mesh sieve) were subjected to magnetic concentration, using a current of 0.5 amperes. The magnetic heads weighed 36 grammes. A comparison be-

tween the quantities of iron, sulphur, silica, nickel and cobalt present in the dike and in the concentrates is afforded by the following analyses:

	Dike.	Concentrates.
Fe,	15.71	32.60
S,	.21	.15
SiO_2,	45.13	40.50
Ni and Co,	.73	1.87

These analyses show not only that the proportion of iron is increased in the concentrates, but also that of the nickel and cobalt, while at the same time the proportion of sulphur is somewhat lessened. From these results it may be inferred that between the magnetite (which is titaniferous) in these dikes and the nickel and cobalt, there is an intimate association. These results would, therefore, support the theory (page 398) that in the titaniferous ores nickel (also cobalt) occurs as the oxide of a spinel molecule.

Although the percentage of nickel so far obtained in these titaniferous magnetites is small, yet there is reason for believing that magnetites may be found containing a higher percentage of this metal than those already examined. In this connection it is to be remembered that some of the Canadian pyrrhotites, which are also believed to be of igneous origin, contain amounts of nickel which make them valuable as ores, while others contain the metal in only traces.

These titaniferous ore-bodies, although occurring in enormous masses in Canada and various localities in the United States, have so far baffled economic reduction, and by many are regarded as beyond present metallurgical methods. In a recent paper,* formulating the results of experiments carried on in a small experimental furnace at Buffalo, A. J. Rossi claims to have obviated the difficulties. But whatever may be the opinion of metallurgists regarding the possibility of smelting these ores, there appears to be a general appreciation of the special qualities of the metal obtained from them. The superior quality of such iron has been thought by some metallurgists to be due to the absence of phosphorus; others regard it as due to the presence of titanium. In a general manner it may be said that if it is due to the presence of titanium, very small quantities of

* *The Iron Age*, February 6 and 20, 1896.

this substance are then sufficient to secure these results. "In our blast-furnace tests we have not been able to obtain more than a few hundredths to one-tenth of 1 per cent. of titanium . . . . and still the qualities of the pig metal and iron were exceptionally good."*

The fact that iron produced from titaniferous ores is of a very high quality may have some connection with the occurrence of nickel in these ores. Even a very small percentage of nickel in an iron-ore would be of value if the total nickel present could be extracted along with the iron in smelting, as the resulting alloy might be used directly in the production of nickel steel. In this connection a sample of pig-iron—the product of Mr. Rossi's experiments on titaniferous ores at Buffalo—was examined for nickel, and found to contain 0.11 per cent. Samples of the ore, however, upon which Mr. Rossi's experiments were made, I have not been able to secure. Consequently, I have not been able to ascertain what proportion of the nickel in the ore is extracted with the iron in a blast-furnace operation. However, in order to arrive at some idea regarding this important question, 100 grammes of the Lutterworth dike, pulverized to 100-mesh and fluxed according to Percy's minimum charge, were fused in a brasque-lined crucible. A small button of iron was obtained. Analyzed, it was found to contain 11.6 grammes of iron and 0.58 gramme of nickel and cobalt. The calculated amounts of these metals (based upon the analysis at bottom of this page)† present in the 100 grammes would be 13.7 grammes of iron and 0.73

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* *The Iron Age*, February 6 and 20, 1896.

† Analysis of Lutterworth dike:

Ni and Co,	0.73
FeO,	13.11
Fe_2O_3,	5.22
CaO,	10.32
MgO,	5.78
Na_2O,	1.01
K_2O,	.87
SiO_2,	44.91
TiO_2,	1.84
Al_2O_3,	14.41
S,	.12
Moisture, etc.,	1.13
	99.45

gramme of nickel and cobalt. From these results it may be inferred that nickel would be as easily reduced and collected in a blast-furnace as iron.

Examination of Titaniferous Magnetites for Platinum.

The occurrence of platinum in igneous and metamorphic rocks of the general type met with in association with the titaniferous magnetites, previously described, suggested the possibility of the metal being present in the ores. In almost all of the hitherto described platinum localities the associated rocks have been peridotites, or serpentines which are themselves altered peridotites or pyroxenites. Thus, at Tagilsk and Biserk, Russia, the platiniferous area is completely bounded by serpentine rocks, while in California the placers containing platinum are always in close proximity to serpentine.

Recently, Emmens* found platinum to the extent of 0.25 per cent. in the nickel oxide manufactured by the Orford Copper Company from Sudbury matte. The pyrrhotite and chalcopyrite from which the matte was produced are regarded as constituting a basic segregation in a more or less metamorphosed diabase or gabbro.

These facts suggested that platinum might be present in the segregated titaniferous magnetites occurring in gabbros, and containing a small proportion of nickel. Two hundred grammes of ore from the Pine Lake (p. 378), Horton (p. 379), and Chaffey (p. 377) ore-bodies, respectively, were assayed for this metal, but in no instance could the faintest trace be detected.

The Elimination of Titanic Oxide from Titaniferous Magnetite by Magnetic Concentration.

Many have suggested, and some have claimed, the possibility of reducing titanic oxide in titaniferous magnetites by magnetic concentration. Nothing definite regarding such a concentration appearing in the literature at my disposal, a number of experiments were conducted to ascertain if such a separation might be effected. The experiments were made with a Wetherell magnetic concentrator at Newark, N. J. The ore in each case was crushed so as to pass through a 40-mesh but not through a 60-mesh.

* *Min. Industry*, 1892, vol. i., p. 377.

I. *Eagle Lake Ore.*—As already remarked, the ore is characteristically homogeneous, even thin sections under the microscope failing to exhibit any foreign constituent. The first attempt to effect a separation was made, using the current from a single small dry cell. Every particle of ore was picked up by the magnet. Other attempts were made having the current further reduced, but as long as the current was of sufficient strength to enable the magnet to attract a single particle, every particle within the field was picked up. Thus, for this ore, no separation whatever could be effected.

II. *Pine Lake Ore.*—This ore has already been described as being impregnated with more or less augite, and contains 13.52 per cent. of titanic oxide and 43.38 per cent. of metallic iron. The sample treated weighed 380 grammes. The results obtained are shown in the following table:

	Sample.	Current.	Weight of Heads.	Per Cent. of TiO_2.	Per Cent. of Fe.
			Grammes.		
I....	Ore.	Single dry cell.	272.0	18.10	56.45
II....	Tailings from I.	2 amperes.	17.3	1.62	......
III....	Tailings from II.	5 "	7.8	1.41	......
IV....	Tailings from III.	10 "	3.1	1.29	......
V ...	Tailings from IV.	15 "	2.0	1.35	......
VI....	Tailings from V.	17 "	3.1	1.30	......
Final tails			64.0	1.19	5.33
Lost			10.7		

From the above it is to be observed that as a result of the magnetic concentration the percentage of metallic iron has increased from 43.38 per cent. in the ore to 56.45 per cent. in the heads, but at the same time the titanic oxide has increased from 13.5 per cent. to 18.1. Fractionally expressed, the metallic iron has increased by $\frac{10}{33}$, while the titanic oxide has increased by $\frac{11}{33}$. From this close relation in the increase of percentage, it may be inferred that in this ore the titanic and iron oxides are at least intimately associated, if not chemically combined.

III. *Chuffey Ore.*—This ore, which is fine-grained, contains a small amount of pyroxene and of pyrite. A sample containing more than the average quantity of pyrite was selected, in order to more readily ascertain the proportion of sulphur which would

be eliminated by the magnetic concentration. A current of 0.25 ampere was used.

	Ore. Grammes.	Heads. Grammes.	Tails. Grammes.
Weight,	720	640	73
	Per cent.	Per Cent.	Per Cent.
Fe,	53.0	56.1	27.0
TiO_2,	7.4	5.0	29.9
S,	1.5	1.3	2.8
SiO_2,	7.0	6.2	14.6

From these results it is to be observed that the magnetic concentration of this ore has effected a partial removal of silica, sulphur, and titanium, while the proportion of metallic iron has been slightly increased. The fact that the tails, which constitute only one-ninth of the original sample, contain two-fifths of the whole titanic oxide is particularly noteworthy. This would show that at least a portion of the titanium occurs in this ore in a non-magnetic combination, and since the sample treated would not pass through a 60-mesh, it would also indicate that this non-magnetic titaniferous combination forms particles of considerable size. From this it may be inferred that in some titaniferous ore-bodies, where the conditions of temperature and pressure at the time of segregation differed from those under which the Chaffey ore-body was formed, these titaniferous particles might be larger, and thus permit of a more complete magnetic elimination of the titanic oxide. On the other hand, in those cases where the proportion of titanium cannot be reduced by magnetic concentration it is probably due to the fact that the titaniferous constituent of the ore exists in such small particles that it is held mechanically by the magnetic portion.

Besides the three general occurrences of magnetite previously cited, there are also found along shore-lines, in various parts of the world, siliceous sands containing a greater or less proportion of heavy black grains, which consist chiefly of iron minerals. The proportion of these minerals to the whole mass of sand is generally very small. In places, however, the action of moving water has effected a concentration of the heavier ferruginous constituents, giving rise to accumulations of so-called iron sands. Such beds are at present forming in various localities, as along the shores of the Lower St. Lawrence, the

Mediterranean, the Baltic, Lake Superior, etc. The source of the minerals comprising these beds is easily traced to the various crystalline rocks which, by their disintegration, have given rise to the siliceous sands. Hence, as might be expected, these "iron sands" contain iron in the various ore-combinations found in the different crystalline rocks, as hematite, magnetite, ilmenite, etc. Some of these sands are completely magnetic and non-titaniferous. On the other hand, others, by means of a magnet, can be separated into a magnetic portion which is free from titanium and a non-magnetic part which is chiefly titanic iron. Thus an "iron sand" from the north shore of Lake Superior, when treated with a small hand-magnet, yielded grains quite free from titanium, which were evidently pure magnetite. The remaining black grains were found to contain 47.8 per cent. of titanic oxide.*

Many of the schists and gneisses found in Archæan areas are believed to be metamorphosed sediments or beach-deposits, and the iron ore-bodies which they contain are regarded as having a similar genesis. If the original "iron sand" which afforded these ore-bodies contained both magnetite and titaniferous iron, the resulting ore would undoubtedly be titaniferous; and if the metamorphism had not been too pronounced, the ore might, when crushed, be resolved by means of a magnet into a magnetic and non-magnetic portion. Probably some of the titaniferous ores, in which the proportion of titanic oxide is reported to have been largely reduced by magnetic concentration, have had such an origin.

Coal-Cutting Machinery.*

BY EDWARD W. PARKER, WASHINGTON, D. C.

(New York Meeting, February, 1899.)

Introduction.

One of the most important features of the coal-mining industry of the present day is one that is common to the majority of industrial enterprises—the substitution of mechanical methods for hand-labor.

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* Presented by permission of the Director of the United States Geological Survey.

The present paper is intended to discuss the mechanical devices which have been introduced for under-cutting and shearing or for the actual mining of bituminous coal. In order to confine the discussion within reasonable limits, I have deemed it advisable to consider only those machines which are in successful operation in the United States. No attempt has been made to prepare even a partial history of the development of coal-cutting machines abroad as well as at home. To do justice to that subject would require fully half of an ordinary volume of the *Transactions*. The present paper is designed to show particularly the existing state of machine-mining in this country. Any historical notes here given are merely incidental and necessarily incomplete, while the only references to machines of foreign manufacture are made to some (like the Stanley entry-driving machine) upon which patents have been taken out in the United States.

Part of the material submitted herewith is obtained from a brief statistical statement which I presented in connection with my report on the production of coal for the annual volume, *Mineral Resources of the United States*, 1897, published as a part of the Nineteenth Annual Report of the United States Geological Survey. The bulk of the paper, however, has been prepared from information obtained by correspondence and personal interviews with the concerns manufacturing coal-cutting machinery, and by visits to some of the factories, and to several mines equipped with machines.

In collecting the statistics for 1896, the request was made for corresponding data covering the calendar year 1891, in order that the growth in the use of mining-machinery during a period of five years might be observed. Considering that this was the first attempt to secure this information, the results obtained were remarkably complete. They show that in 1891 there were only 51 firms and corporations using coal-cutting machinery, and that the total number of machines in use in that year was 545. These firms and machines were distributed among 8 States and produced a total of 6,211,732 short tons, an average of about 11,400 tons per year, or not quite 1000 tons per month, for each machine. The entire output from the same 8 States in that year was 93,177,978 short tons; so

that the machine-mined product represented a little less than 7 per cent. of the total tonnage of those States, and was 5.3 per cent. of the total bituminous coal-product of the United States. In 1896 mining-machines were in use in 16 States, an increase of 100 per cent., while the number of firms using machines had increased 167 per cent., to 136; the number of machines in operation 165 per cent., to 1446; and the machine-mined tonnage had increased in almost exact ratio, or 165 per cent., to 16,424,932 short tons. These 16 States produced a total of 115,921,828 short tons in 1896, of which a little more than 14 per cent. was won by machines; and as the aggregate bituminous product in 1896 was 137,640,276 short tons, the machine-mined product constituted 12 per cent.; these percentages having been 7 and 5.3 respectively in 1891. The average tonnage for each machine in 1896 was 11,373, about 25 tons less than in 1891.

The year 1897 showed a notable advance in the use of mining-machinery. The number of firms having mines equipped with machines increased 75, as against an increase of 85 from 1891 to 1896. The number of machines in use increased from 1446 in 1896 to 1988, showing a gain of 542, or 37.5 per cent., whereas the average gain from 1891 to 1896 was about 22 per cent. The tonnage won by machines in 1897 was over 6,200,000 tons greater than in 1896, and equivalent to 60 per cent. of the increase in 1896 over 1891. Six States were added to the number having mines equipped with cutting-machines; but two mines, one each in Utah and Washington, which used machines in 1896, did not operate them in 1897; and as these were the only machines in those States, there was a net gain of four in the number of States, making a total of 20. The total tonnage won by machines in 20 States in 1897 was 22,649,220 short tons, 16.17 per cent. of the total product of those States, and 15.3 per cent. of the total bituminous product of the United States. One of the striking features of the figures presented is the uniformity shown in the average producing capacity per year of each machine, which was 11,398 tons in 1891; 11,373 tons in 1896; and 11,393 tons in 1897.

In considering the growth of the use of mining-machines by States, some curiosities of statistics are exhibited. In 1891,

Ohio, then the third State in rank of producing importance, had the largest number of firms employing machines, with a total of 19; Illinois, the second State in rank, came next with 16; while in Pennsylvania, the bituminous coal-product of which exceeded by 50 per cent. the combined output of Ohio and Illinois, there were only 7 concerns using machines. In the number of machines in use in 1891, Illinois came first with 241; Ohio second, with 114; and Pennsylvania third, with 72. Illinois also led in the tonnage, having 3,027,305 tons, against 1,654,081 tons for Ohio and 431,440 tons for Pennsylvania. But when we consider the figures for 1897, a decided difference is to be observed. The number of firms using machines in Illinois was a little more than doubled, the number of machines in use increased one-third, while a gain of 30 per cent. is shown in the tonnage. The number of firms in Ohio also doubled, with an increase of machines in nearly equal proportions, while the machine-mined product increased 130 per cent. In Pennsylvania the greatest gain is shown. The number of firms in 1897 was 9 times that of 1891, the number of machines in use was multiplied by 9½, while the tonnage mined by machines was more than 20 times what it had been six years before. In the State of Indiana, the number of firms had increased in the same period from 3 to 11; the number of machines from 47 to 174; and the tonnage from 212,830 to 1,023,361. It is probable that the quality and cheapness of mining labor in West Virginia has militated against the more rapid introduction of machines into the mines of that State, for out of a product of over 9,000,000 tons in 1891, only a little more than 200,000 tons, or 2.23 per cent., were machine-mined, while in 1897, out of a total of about 14,250,000 tons, only 673,523 tons, or 4¾ per cent., were won by machines. It is also highly probable, on the other hand, that the cheaply-mined product of West Virginia has exerted a considerable influence upon the introduction of machines in the other four States mentioned, in order to lessen the cost of production and compete in common markets with this otherwise favored rival.

The remarkable increase in the amount of coal mined by machines has undoubtedly had much to do with lessening the cost of coal to the consumers. Prices have been steadily declining

for several years, the average price per ton for bituminous coal at the mines having declined from $1.12 in 1887 to 81 cents in 1897. In some cases, prices have been reduced on account of the lessened cost of production; in other instances machines have been introduced in order to meet competition. In many cases, so far as my observation goes, much of the benefit that might have been derived from the use of machines has been sacrificed in the effort to increase tonnage and add to the supply of an already glutted market, rather than to continue previous output with a shortened pay-roll.

The following table, taken from the Survey Report, shows in detail the statistics of the production of coal by the use of machines in 1891, 1896 and 1897. The figures of total production are omitted in cases where no product by machines was reported.

These statistics are presented as a sort of introduction to the brief history of coal-cutting machinery, and the descriptions of a few of the machines now in use, which follow.

When I undertook the preparation of this paper I was somewhat at a loss to know where to begin. A visit to the U. S. Patent Office and an examination of its files developed the fact that the first patent for an under-cutting machine (No. 21,908) was issued to Elisha Simkins, of Allegheny, Pa., as far back as 1858, since which time no less than 468 patents have been issued. The number of the latest patent (issued in 1898) is between 600,000 and 700,000. I concluded that it was not possible, within the limited time at my disposal, to attempt to study out from the Patent Office files an intelligible history of the mining-machines.* I determined, therefore, to limit this paper to a discussion of those machines which have survived the test of practice, and have shown by actual use the success of applying mechanical methods to the mining of bituminous coal. I have drawn upon the manufacturers and operators for informa-

* Through the courtesy of Mr. Lewis B. Wynne, chief examiner in this section of the machinery division of the Patent Office, I have been able to secure copies of some of the drawings and specifications of patents issued on coal-cutting machinery. I did not wish to appear unreasonable in my demands, and accordingly asked for copies of specifications on such patents as have had an influence on the present perfected machines. Consequently I took only about 50 of the 468.

Bituminous Coal Mined by Machines in Twenty-two States in 1891, 1896 *and* 1897.

State.	Number of Firms Using Machines.			Number of Machines in Use			Number of Tons Mined by Machines.		
	1891.	1896.	1897.	1891.	1896.	1897.	1891.	1896.	1897.
Alabama			3			45			294,384
Alaska		1	1		6	6		15,232	17,920
Arkansas		1	1		14	15		21,094	87,532
Colorado	1	6	8	20	34	37	284,646	318,172	352,400
Illinois	16	21	35	241	307	320	3,027,305	3,871,410	3,946,257
Indiana	3	11	11	47	186	174	212,830	964,378	1,023,361
Indian Territory		3	3		56	54		191,585	263,811
Iowa	2	5	7	9	45	67	41,540	84,556	181,209
Kansas			1			1			4,500
Kentucky			13			162			1,299,436
Missouri		1	1		4	3		47,827	59,692
Montana		3	2		62	61		579,414	720,345
North Dakota		1	1		1	2		15,000	20,000
Ohio	19	31	39	114	209	224	1,664,081	3,368,349	3,843,345
Pennsylvania	7	41	64	72	454	690	431,440	6,092,644	8,925,298
Tennessee			2			8			47,207
Texas			1			5			11,750
Utah		1			1			760	
Virginia			1			22			323,649
Washington		1			8			3,920	
West Virginia	1	7	13	8	25	47	205,784	430,944	678,523
Wyoming	2	2	4	34	39	45	354,106	419,647	555,526
Total	51	136	211	545	1,446	1,988	6,211,732	16,424,932	22,649,220

Bituminous Coal Mined by Machines in Twenty-two States in 1891, 1896 *and* 1897.—*Continued.*

State.	Total Tonnage.			Percentage of Total Production by Machines		
	1891.	1896.	1897.	1891.	1896.	1897.
Alabama			5,893,770			4.99
Alaska		15,232	17,920		100 00	100 00
Arkansas		675,374	850,190		3 12	10.30
Colorado	3,512,632	3,112,400	3,361,703	8 10	10 22	10.48
Illinois	15,660,698	19,786,626	20,072,758	19.33	19 57	19.66
Indiana	[illegible]	3,905,779	4,151,169	7.16	24.69	24.65
Indian Territory		1,366,646	1,336,380		14.02	19.74
Iowa	[illegible]	[illegible]	4,611,865	1.69	2.14	3.93
Kansas			3,054,012			0.15
Kentucky			3,602,097			36.07
Missouri		2,331,542	2,665,626		2.56	2.24
Montana		1,543,445	1,645,799		37.54	43.77
North Dakota		78,050	77,246		19.22	25.89
Ohio	12,868,683	12,875,202	12,196,942	12.85	26.16	31.51
Pennsylvania	[illegible]	[illegible]	54,597,891	1.01	12.29	16.35
Tennessee			2,888,849			1.63
Texas			639,341			1.84
Utah		[illegible]			0.18	
Virginia			1,528,302			21.18
Washington		1,195,504			0.33	
West Virginia	[illegible]	12,876,296	14,248,159	2.23	3.35	4.73
Wyoming	2,327,811	2,229,624	2,597,886	15.21	18.82	21.38
Total	93,177,978	115,921,828	140,037,905	6.66	14.17	16.17

tion, and am more than gratified to be able to say that they have responded with unfailing courtesy to heavy and repeated drafts upon their time and patience.*

It was about twenty years after the first United States patent was obtained that the practicability and economy of cutting coal by machinery in this country was demonstrated. On Christmas day, 1877, the first patent (No. 198,610) on a punching- or pick-machine was issued to J. W. Harrison. The improved Harrison machine is now manufactured by the Geo. D. Whitcomb Company, of Chicago, Ill. Subsequent patents on the Harrison machine were issued on Sept. 2, 1879; Sept. 28, 1880; June 20, 1882; July 25, 1882; Aug. 8, 1882; Nov. 7, 1882; July 3, 1883; Feb. 2, 1886; Feb. 19, 1889. Reissues, Oct. 12, 1880; Nov. 2, 1890.

In 1876 the Lechner Mining Machine Co., succeeded later by the Jeffrey Manufacturing Company, of Columbus, Ohio, working under patents issued to F. M. Lechner, turned out the first cutter-bar breast-machine. The first few years of the use of mining-machines were years of trials and tribulations for the makers and users. Difficulties were developed that had not been anticipated. It was soon shown that a machine capable of doing good work on clean soft coal was a very uncertain factor in harder coal or when a band of sulphur in the form of pyrite, or other hard substance, was encountered. Lack of proper control when the "load" was suddenly taken away caused the machines to "race" with disastrous results. These defects have been overcome by the strengthening of parts where weakness was developed; by providing air-cushioning for taking up the shock in machines of the pick type when the cutter misses the coal; and by better control, sometimes automatic, of the motive power. Still another difficulty which the machines have had to face was the opposition of the labor organizations. This opposition has been, it is claimed, shown in a practical manner, and it is also claimed that much of the sup-

* I wish in particular to acknowledge the assistance furnished by Messrs. Hutchins, Miller and Palmros, of the Jeffrey Manufacturing Company; Messrs. Goodman and Sheafer, of the Link-Belt Machine Company; Messrs. Gardner and Ryan, of the Morgan-Gardner Electric Company; Messrs. Copeland and Jarvis, of the Sullivan Machinery Company; Mr. W. C. Whitcomb, of the Geo. D. Whitcomb Company; Mr. Geo. R. Murray, of the Ingersoll-Sergeant Drill Company; and Mr. E. C. Morgan, of the Morgan Standard Company.

posed imperfections and inefficiency of the earlier machines were due to the handling of the machine by the miner, who saw in it a supplanter of his labor, and therefore an enemy to be dealt with as harshly as possible. The manufacturers and operators are still contending with this opposition, which now takes the form of a demand by the miners' union for such a rate on machine-mined coal and such wages for the loaders who follow the machine as, if paid, would absorb the operator's profits from his investment.

The earlier types of coal-cutting machinery were all driven by compressed air, and it was not until 1889 that electricity was applied to the cutter-bar machine by the Jeffrey Manufacturing Company. Air continues to be the exclusive motive power employed for pick-machines, the modern types of which do not differ from the original plans except in the particulars previously stated. The cutter-bar machines have, however, been superseded. Electricity was successfully applied to the cutter-bar machine in 1889, but five years later (in 1894) the Jeffrey Manufacturing Company brought out the chain breast-machine, which proved so superior to the other style that the manufacture of it immediately ceased. Some of the cutter-bar machines, built prior to 1890, are, however, still in use, and doing good service.

The two types of machine most in use to-day are the pick- and the chain breast-machines, although one may still find occasionally a Sperry, a Yoch or a Stanley, while a long-wall machine, recently brought out by the Jeffrey Manufacturing Company, has found a place in some of the thin seams of the Western States. The Sullivan Machinery Company, of Chicago, has also recently brought out a long-wall machine, which is claimed to do good work; but it is still in the experimental stage, and, until it has passed this stage, the manufacturers prefer to postpone discussion of it. It may be stated, however, that the machine has a chain side-cutter, propels itself along the face of the coal by a rope, and does away with any track or support. The long-wall system of mining is not practiced in this country to the same extent that it is in Europe, and most of this class of mining-machines made in the United States have been exported to Europe. I am informed by the manufacturers that as soon as one of these machines is placed in an

English mine it is lost to the world. Not only do the mine-operators decline to give any statement as to the record made by the machines, but access to the mine where the machines are in operation is refused. The machine stays in the mine, is repaired there, and the only intimation that its maker has that it has accomplished anything at all is by the receipt of an order for one or more additional machines.

These types of mining-machines have been brought to such a degree of efficiency that it is safe to say that there are comparatively few bituminous coal-mines operated upon an extensive scale that could not with advantage be equipped with mining-machines. There is but one adverse condition that has not been successfully surmounted, and that is the inclination of the vein when the dip exceeds 12° or 15°. Some of the pick-machines have been used in mines where the inclination was as much as 23°; but the work was slow and difficult, and it was only from the fact that the price of labor was high that the machine was able to compete with it. The trouble does not lie so much in the actual cutting, but in the difficulty of moving the machines from place to place. Manufacturers do not care to run the risk of failing, and prefer not to install machines where the dip exceeds, say, 14°. By the use of self-propelling trucks, it has been possible to use chain-machines in mines having this amount of inclination from the horizontal; but that is about the maximum. The self-propelling truck also enables the chain-machine to be used in mines where the seam is so thin that it would be otherwise impossible to draw the machine or move it up to the face of the coal, as neither horses nor mules could go into the room unless some of the floor were taken up or the top taken down.

There are seven concerns in the United States engaged in the manufacture of coal-mining machinery, as follows:

The George D. Whitcomb Company, Chicago, Ill., manufacturer of the Harrison pick-machine, with compressed air.

The Jeffrey Manufacturing Company, Columbus, Ohio, manufacturer of chain breast- and long-wall machines for either compressed air or electricity. Also chain shearing-machine.

Sullivan Machinery Company, Chicago, Ill. (works at Claremont, N. H.), manufacturer of the Sullivan pick-machine, using compressed air.

Ingersoll-Sergeant Drill Company (works at Easton, Pa.), manufacturer of the Sergeant pick-machine for use with compressed air.

Link-Belt Machinery Company, Chicago, Ill., manufacturer of the Independent, electric chain breast-machine.

Morgan-Gardner Electric Company, Chicago, Ill., manufacturer of chain-breast and shearing-machines driven by electricity. This concern has also recently brought out a pick-machine which it is claimed can be successfully operated by electricity.

Morgan Standard Company, Chicago, Ill. (recently organized), manufacturer of electric chain breast-machines.

In addition to these, a few chain-machines have been made by the General Electric Company.

It will be seen from the foregoing that pick-machines driven by compressed air are made by three separate concerns, and that four companies are making electric chain-machines, and one of these four is also making a chain-machine driven by compressed air. One makes a long-wall machine, and one is bringing out a pick-machine for electric power. All of the air-driven pick-machines may be converted into shearing-machines by simple means, and can also be made to do long-wall work by using a shorter striking-arm and a longer supply-hose. The chain-machines are made to do shearing-work by having the cutting-parts turned at right angles to the position occupied when making an undercut. One concern only, the Jeffrey Company, makes a specialty of a separate long-wall machine, although, as stated, the Sullivan Machinery Company is experimenting with a new machine of this type.

Pick-Machines.

As already remarked, the general style of the pick- or punching-machine is not materially different to-day from what it was twenty years ago, and the several makes of to-day differ only in unimportant details of construction, which would be unimportant, except that on them are based claims of superiority for each machine over all others. One has some special feature here, another there, etc., like the new features in bicycles brought out each year; and, like standard bicycles, they all have their admirers. As a result of a somewhat extended trip in which I visited most of the factories, or selling agencies,

and then a number of mines in which the machines were at work, I learned that each machine was the best. This was not based solely upon the claims of the manufacturers or their agents, but upon the statements of the operators, and even included the testimony of the runner, each one seeming to think that his particular machine was the machine *par excellence.*

For instance, for one machine is claimed certain advantages "which are not even *approximately* approached by other machines of its class." Another says: "The practical commonsense advantages of our construction in every line, theory aside, appeal with conviction to the best judgment and self-interest of the most progressive trade. The most notable and advanced installations of late are of our machinery. We will not relinquish our leading position, and in this age of rapid improvement will continue to lead. Buyers may rest assured that if there are real improvements, we have improved on these improvements, and that our product will always be found in advance of the best practice of others." A third says: "We have proven our under-cutters to have no equal in the amount of coal cut, cost of repairs and consumption of air." These are all instances of the same type of machine.

The method of attacking the coal is as follows: The runner sits behind the machine, which is set upon an inclined platform, the angle of which holds the machine to the coal. The blow is struck in much the same way as the outward stroke is given to the piston-rod of an engine, except that compressed air, instead of steam, is the motive force. A shallow hole is first cut in the face of the coal, even with the floor. A few blows just above the hole break down enough coal and clear a way for the runner to deepen the original cut. He works his machine backward and forward on the platform along the face of the coal, the work being comparatively easy as soon as the first cut has been made to a sufficient depth. The runner uses a block attached to the sole of his shoe, to "chock" the wheels of the machine against the effects of the recoil from the blow. This has been found much more satisfactory than using a stone or block of wood, ratchet-wheel or other independent brace, as the runner receives little if any punishment, and has better control and is more in touch with his machine all the time. The platform upon which he operates has about the same width

as the cut intended to be made, and can be made in duplicate, so that when he is near the end of one cut his helper may place the other section beside it, and the machine may be moved from one to the other with little loss of time. As a usual thing, however, only one platform is used in a room. The helper is also expected to keep the cut as free as possible from the slack and small coal made in the cutting, so that, once placed in position, the runner has little to do except to manipulate and shift his machine, until the face is under-cut entirely across the room. The machine is then removed to another room and the first one is shot down. One of the advantages claimed for the pick-machine is that, as the cut is V-shaped, with the wider part at the front, the coal will shoot down more perfectly, and does not have to be pulled down with a pick after the shot. Another admitted advantage of the pick-machine is that it may be used in mines where conditions of roof and floor will not permit the introduction of the chain breast-machine.

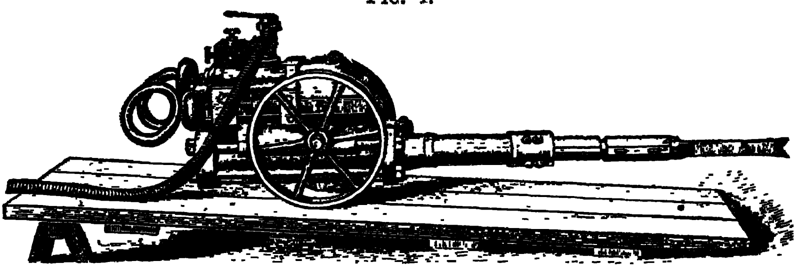
It is in many instances necessary to bring the timbering up to within 3 or 4 feet of the face of the coal, in which case the use of a chain-machine, requiring 10 or 12 feet of clear space between the face of the coal and the supports of the roof, is manifestly impossible. In other cases, such as the frequent occurrence in the bottom of the coal of pyrite or other hard materials, which would break the bits of a chain-machine, if not the machine itself, the pick-machine has the advantage, as the runner is able to cut around the obstruction instead of being obliged to cut through it. Another advantage claimed for this type of machine (but which applies also with equal force to the chain-breast or long-wall machines driven by compressed air) is that, in mines where the quantity of gas is so great that safety-lamps have to be employed, the danger of explosion, which might be caused by an electric spark from the motor, is obviated.

The Harrison Machine.

This machine, now manufactured by the Geo. D. Whitcomb Company, of Chicago, is unquestionably the pioneer machine of the pick type, and was one of the first to demonstrate successfully the possibility of substituting mechanical methods for hand-labor in the under-cutting of bituminous coal. The first machine turned out by this company was placed upon the mar-

ket in the spring of 1880 (the first patent was issued to J. W. Harrison in December, 1877), so that this company has now a record of nineteen years in the manufacture of coal-mining machinery, and has consistently stuck to the pick-machine, although two patents on a different type of machine were taken out by Mr. Geo. D. Whitcomb, one in 1871 and one in 1876. When first offered to coal-operators the machine was met with prejudices which were not easily overcome. Operators had to be convinced that it was practicable to under-cut coal by machinery, so that the pioneers had in this respect, as well as in the mechanical defects, and the opposition of the miners' unions, a great deal of difficulty to overcome. In time, however, operators still employing hand-labor learned that some of their competitors were effecting a satisfactory saving in the cost of mining by the use of machines, so that now we find the ques-

FIG. 1.



Harrison Pick-Machine, Class B.

tion asked by operators is, not whether the use of machines is a demonstrated success, but what type of machine is going to perform the best work with least cost, considering all the conditions of the mine, the original cost of installation, and the expense of maintenance and operation.

Since 1880 the Whitcomb Company has turned out about 1700 pick-machines, and while some of the very first ones made have been discarded, there are still in use many of the machines made in 1880 and 1881, and they seem to be giving entire satisfaction. All parts of each pattern are made interchangeable to facilitate and cheapen repairs.

The following statements concerning this machine are practically those of the manufacturers:

The Harrison machines were first designed to work on a delivered pressure of 45 pounds per square inch. The opinion then

prevailed that low pressures resulted in the greatest efficiency and economy. This is the case only when the machines are operated near the compressor. In mining practice, they must be supplied with air through pipes that are constantly increased

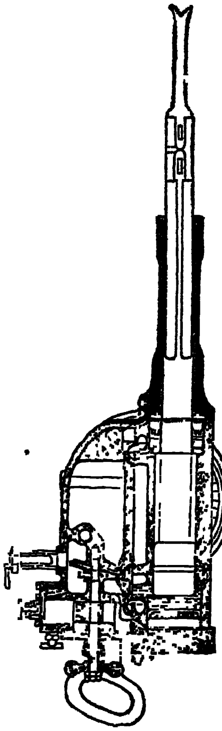


FIG. 2.

Longitudinal Section of Harrison Pick-Machine.

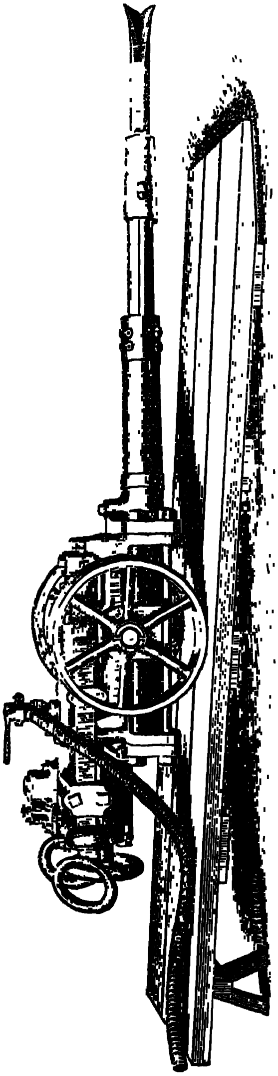


FIG. 3.

Harrison Pick Machine, Class F.

in length as the entries are projected, until, in some mines, the distance between compressor and machines exceeds 2 miles.

As the loss of pressure by the flow of air through pipes varies directly with the length and with the square of the

velocity, it is evident that, by the use of higher pressures, a much larger ratio of the energy of compressed air is delivered at the working-faces of the rooms in mines. This was proved when machines were designed for a pressure of 60 pounds per square inch. After working on this basis for a short time, the manufacturers designed and constructed the machines for a pressure of 75 pounds per square inch; and the result has been a satisfactory further increase of efficiency.

In order to attain the desired results as mentioned, it has been necessary to have the valve-movement of the machine uniform and reliable so as to cut off at less than half of the piston-stroke, when the machine is being operated at a speed of 190 to 200 strokes per minute, regardless of the position of the piston when the pick is stopped by contact with the coal. This has been successfully accomplished by the use of a valve-motor, designed expressly for this work. It is entirely independent of the action of the piston, is very small, uses but little air, and operates the valve with a uniformity and certainty that secures an early cut-off, the expansive energy of the air and an appreciable amount of economy.

The working-tool of a machine of this class is in principle a projectile, and the energy of the blow is measured by its weight and velocity; therefore, after the piston, with the pick attached, has acquired the required velocity, it is not only economical of power to have the valve cut off the inlet of the air to the cylinder prior to half-stroke, but it greatly reduces the recoil of the machine upon the operator, reducing his fatigue and enabling him to keep the machine in better working-position.

The piston-rod and extension of the Harrison mining-machine are made of a special homogeneous steel which has been made especially for its use, and which long experience has proved to be the only material that will endure the excessive vibratory and torsional strains to which it is subjected in mining-work.

The picks are likewise made from a special steel and drop-forged in hardened steel dies, so as to secure uniformity and accuracy.

The rear cylinder-head, and the sleeve which forms the forward head, are made of malleable iron and are protected by leather cushions. The cylinder is so constructed that these

cushions are supported by compressed air at the full pressure (75 pounds per square inch) and so confined as to be increased (by actual tests) to 250 pounds per square inch, under heavy blows from the piston, without having the piston-heads hit. The air that supports the cushion does not come in contact with the piston in its regular stroke, and in no way retards the force of the blow.

The machine is mounted on wheels, as shown by the illustrations, the height of the wheels varying according to conditions found in the different mines. The general sizes vary from 16 to 18 inches in diameter. This feature enables the operator to work under or over nodules or segregations of pyrites encountered in mining, and dislodge them. Although it is not claimed that the machine will cut as fast or mine as much per day in hard beds, where pyritic segregations exist in large quantities, yet it is doing good, practical work in very hard material containing large amounts of these impurities. The manufacturers claim that it will mine in any strata where mechanical methods can be used, and that it will mine in strata where it is impossible to use the chain or cutter-bar machines.

The machines are so constructed as to be entirely under control of the operator. The speed can be varied at will, thereby making the blow light and rapid or hard and slow, as occasion requires.

The small size, great strength and simplicity of the Harrison mining-machine make it easy to keep in repair and the cost of repairs light. The only part that comes in contact with the coal is the pick, which is easily removed and replaced by a sharp one when it becomes dull, and which can be sharpened by any blacksmith with an ordinary forge.

The machine is mounted on platforms, which are so inclined to the face of the coal that the recoil of the machine is neutralized by gravity, which also holds the machine to the coal. The pick strikes from 190 to 210 blows per minute, as the operator may desire; and as it works under the coal, the operator allows the machine to run forward down the platform. A helper shovels away accumulated cuttings, using a special long-handled flat shovel. Only two men are required to operate the machine, one skilled man as runner and an ordinary laborer as helper. Two platforms are used for convenience, so that when

the machine has completed the cut on one it can be moved to the next without stopping, the helper shifting the platforms as they are vacated. If desired, a cut to the full depth can be made to the full width of a room without stopping the machine.

The manner in which the Harrison mining-machine attacks the coal is very much like that of a hand-miner. The cut can be made of any desired height or depth as the occasion demands; is generally from 8 to 10 inches in height in front and tapers to 2 inches in the rear, making an average of 6 inches in height. The depth can be made as desired, up to 5½ or 6 feet.

The cut, being V-shaped, leaves the coal in the best possible shape for blasting and loading, as, on being thrown down by a light charge of powder, it will roll over and out of its original position and can be free for attack by the loaders. This feature will be appreciated by all practical mining-managers.

In reply to the inquiries as to the limitations of the Harrison machine, Mr. Whitcomb states that they are two: first, hardness of strata, and second, the ability of the helper to keep the cuttings out of the way of the machine. It is claimed that with this type of machine any strata can be mined that are capable of being mined by a heavy hand-pick, and that in fact coal has been mined by "punching"-machines in mines in which it was impossible to keep hand-miners at work. In the heavier classes of Harrison machines the striking-tool weighs 130 pounds. The stroke is 11 inches, and the machine runs at from 180 to 200 strokes per minute, so that it will be readily seen that the force of the blow is considerable. In some cases, where the seams are thin, a saving is effected by mining-out the underlying fire-clay, which is sometimes very hard. Pick-machines have proved very efficient for this work.

The other limitation, that is, the ability of the helper to keep the cuttings out of the way, is not always thought of. The cut made by the Harrison machine, and, in fact, by all machines of this type, is V-shaped, being from 12 to 14 inches in height in front and tapering down to 2 or 3 inches in the rear, and having, therefore, an average height of 7 inches. In some test-work done in the mines of the Clearfield Bituminous Coal Corporation at Barnesboro, Pennsylvania, this machine undercut as much as 1400 square feet of floor in nine hours' working-time. This 1400 square feet of floor by 7 inches of coal taken

out by the machines, gives 816 cubic feet of solid coal removed by the machines, which, at 80 pounds per cubic foot, will be 65,280 pounds, or at least 32 tons, of coal to be handled by the helper. This is entirely too much for a helper to do regularly. In the mines in that vicinity, where the coal is soft, about 600 square feet of floor per day is the average production of a machine. This is easy work for the runner, but about all that a helper wants to handle.

Another limitation, which Mr. Whitcomb omits to mention, and which applies to all under-cutting machines, lies in the dip of the vein, already discussed in preceding pages.

The average cost of a Harrison machine is $300, and the cost of maintenance, as nearly as it can be ascertained, is from $15 to $30 a year, according to the local conditions. The amount of work done under every-day working-conditions also varies according to circumstances.

In Pennsylvania the amount of work done by the machines differs greatly in different places. In the mines of the Vesta Coal Company, which is the private interest of Jones & Laughlins, they pay all their labor by the day and set a daily task for the machine-runners. They require each runner to under-cut three 30-foot rooms 5 feet deep, that is, 90 linear feet of face by 5 feet deep, equal to 450 square feet of floor under-cut, paying the runners extra for the amount they under-cut over this amount. It is said that the runners will cut their daily task in from seven to eight hours. In the mines around that section this is about the average amount of work done by the machines.

In the mines of the Clearfield Bituminous Coal Corporation Robert A. Shillingford, Superintendent, near Barnesboro, Cambria county, Pa., the runners average about 600 square feet of floor per day; and this is about the average under-cut for that section.

The following table exhibits the amount of coal mined in one year by Harrison machines at the mines of the Consolidated Coal Company in Illinois. This record was taken after the machines had been in use from six to twelve years. It covers sixteen different mines, with widely varying conditions. In some cases the mining is done in the coal; in others it is done in the clay underlying the coal:

Coal Mined by the Harrison Mining-Machine, in the Mines of the Consolidated Coal Company of St. Louis, from July 1, 1893, *to July* 1, 1894.

(Taken from the Illinois State Mine Reports.)

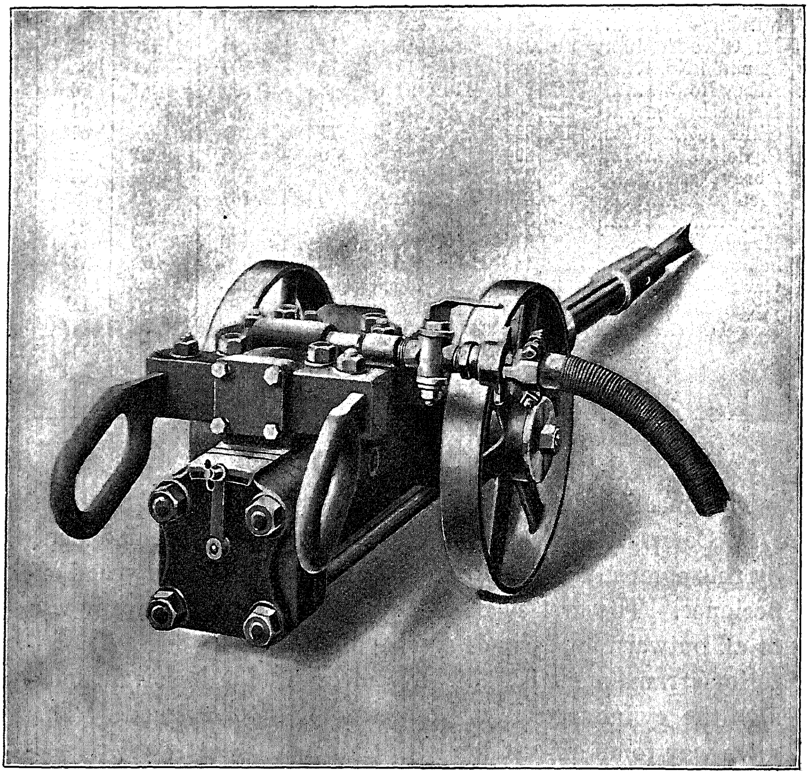
Name of Mine.	Total Tonnage.	Tons of Lump.	Number of Machines Worked.	Days Worked.	Tonnage per Machine per Day.	
					Gross Tonnage.	Tons of Lump.
Staunton No. 6.	255,838	183,148	26	210	47	33
Mt. Olive No. 8....	195,441	137,623	17	160	72	51
Mt. Olive No. 10...	191,925	139,353	14	160	86	62
Staunton No. 7......	142,463	97,919	15	190	50	34
Abbey No. 3.........	139,259	107,191	8	179	97	75
Heintz Bluff.........	122,350	91,640	9	168	81	61
Gillespie..............	112,325	87,845	11	157	65	51
Clyde...................	112,294	85,241	9	183	68	52
Abbey No. 4.........	69,267	52,014	5	163	85	64
Trenton...............	60,376	48,752	9	167	42	32
Troy....................	57,541	42,856	7	166	50	37
Knecht................	42,614	33,040	4	149	72	55
Schureman	38,142	29,186	3	125	102	78
Gartside No. 4......	34,726	30,790	4	125	69	62
Green Mountain...	18,743	15,165	3	73	86	69
Rose Hill............	17,491	13,752	2	118	74	58
	1,610,795	1,195,515	146			

The Ingersoll-Sergeant Machine.

This machine is made at the works of the Ingersoll-Sergeant Drill Company at Easton, Pa. The present pick-machine made by this company is the development of ten or fifteen years' experience. The first machine turned out by this company was to all outward appearance similar to the present one. The interior arrangement is radically different. In the original design the cylinder-head was protected by steel cushions. This gave way to an air-cushion with leather and steel washers, separating the air-chamber from the piston. The present machine has both cylinder-heads protected by simple air-pockets, cushioning on the air-pressure. There is only one main valve, which is driven by an auxiliary valve, which is in turn driven by a rifle-bar arrangement, turned back and forth through a brass nut located in the piston-head. It is claimed that the action of the machine is such that when in contact with the coal it strikes harder and faster than any other machine of the same type. When the runner swings the machine sidewise, or for

any other reason the pick misses the coal, the first blow missed builds up a cushion-pressure which instantaneously throttles down the air-supply, so that, while the machine will keep up its reciprocating motion, it strikes lightly instead of with the full pressure. This is claimed to be the distinctive feature of the latest Ingersoll-Sergeant over other pick-machines, avoiding as it does the full 200- to 300-pound blow when running at full

FIG. 4.



Ingersoll-Sergeant Pick-Machine.

pressure, and making it that much easier on the runner. It is also claimed that this lessens the tendency of the machine to crawl towards the face of the coal, a tendency which is very pronounced when the machine is running at full pressure. Furthermore it gives the runner greater confidence, and enables him when cutting to run the machine much harder than he otherwise would, resulting in an economy of air, as the air is

not used in full force except when the machine is in contact with the coal, and also resulting in greater durability of the machine, as it is relieved of the shock and racking effect of the piston operating under full pressure. It should be stated that when the pick again comes into contact with the coal the full pressure of air is automatically turned on, and the machine immediately runs with full force.

Tests have been made with these machines where undercutting has been done at the rate of 3 square feet a minute of cutting-time. A room 42 feet long has been cut 4½ feet under, from start to finish, in one hour. As it is impossible for one helper to keep the cut clear of slack when running continuously at this rate, the manufacturers feel that they have about attained the maximum efficiency of the pick-machine.

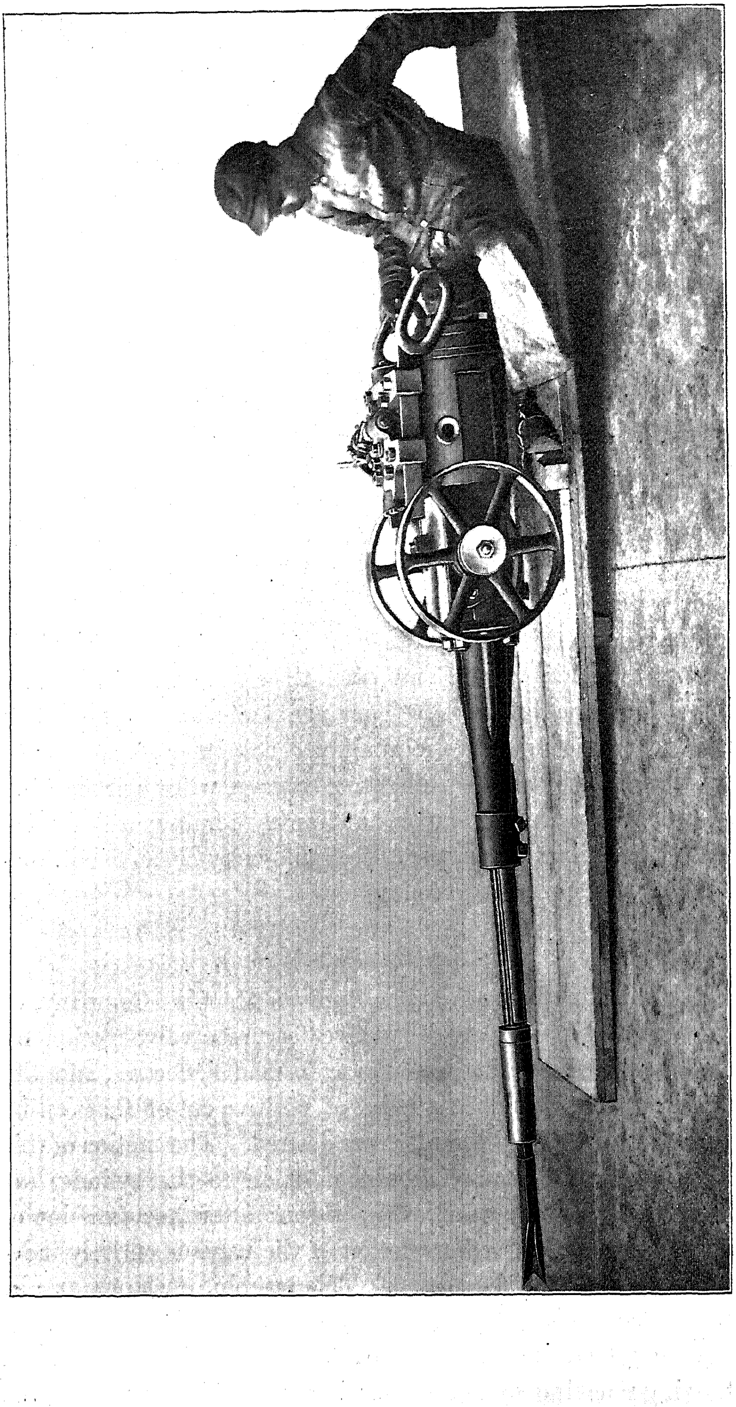
These machines have been used in mines where the coal dipped at an angle of 23°, and, although the progress was slow and difficult, the result could be called successful when the labor conditions were considered. Ordinarily, however, it does not pay to use this or any other pick-machine when the pitch is more than 12° or 14°, and even then accompanying conditions should be favorable. The manufacturers say that they have never encountered a bituminous coal either so hard or so soft that it could not be mined to advantage with their machine as compared with hand-labor, but frankly admit that under extreme conditions of very soft coal and very cheap labor, machines might not prove profitable.

The Sullivan Pick-Machine.

This machine is made by the Sullivan Machine Company, of Chicago, and has for its distinctive feature a valve-motion by which it is claimed that every blow is made effective, and the main feature of which is a point of positive cut-off that can be varied to meet the different blows desired. The motion of this valve during the time of admission of air to the cylinder depends upon the movement of the piston; after the admission of air has ceased, the further motion of the valve is entirely independent of that of the piston. This machine cushions on air, and will not strike the heads should the pick miss the coal.

Although this machine is capable of being converted into a shearing-machine by simply placing it on higher wheels, the

Fig. 5.



Pick-Machine on Platform, Showing Position of Runner.

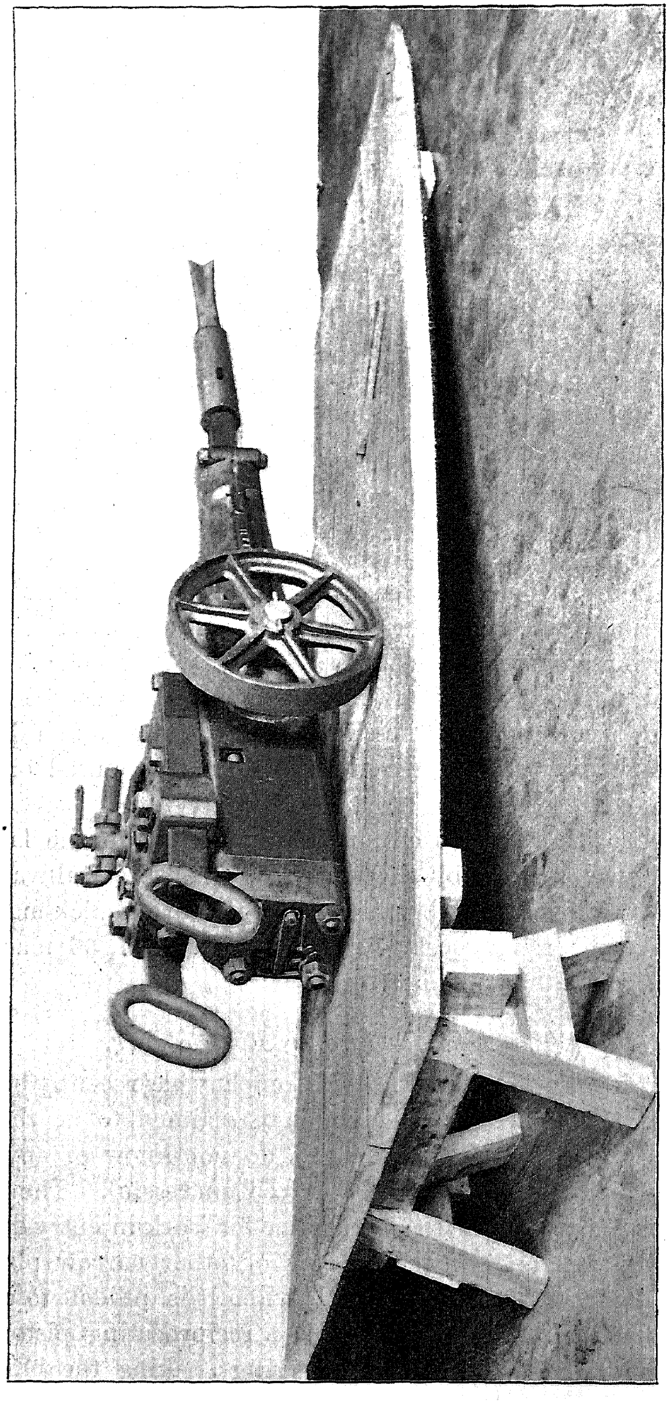
Sullivan Company has not been content to let it rest at that, but has evolved a shearing-machine in which the principle of the pick-cutter is retained. It is, in fact, the pick-machine with an extension-arm and mounted on a special truck, as shown in Figs. 7, 8 and 9. The truck or carriage is built of sufficient strength and weight to take up all the shock of blow and recoil, and neither of these is felt by the runner. The truck is mounted on four wheels, which are kept on the tracks. The forward ends of the tracks are laid up close to the face of the coal and the rear ends are held in place by a jack set to the roof. The machine is held to its work and is fed forward by means of a chain passing over a sprocket-wheel and connected to both ends of the rail. The machine is never taken from the mine-tracks, and is moved from place to place as an ordinary mine-car. The machine makes a cut 6 inches wide, 7 to 8 feet deep, and from the roof to the floor. An eight months' run, operating in a 7½-foot vein, showed an average of 30 feet per shift of ten hours. Two men are required to operate the shearer, one to run it and the other to keep the cut clean. They do all the moving and setting up, and after once becoming accustomed to the work, do it easily and rapidly. The fact that the runner does not receive any of the shock gives the machine a decided advantage over the under-cutting-machine mounted on high wheels.

The growth of the use of mining-machines in the last few years is well shown by the statement that the Sullivan Machinery Company, who began the manufacture of pick-machines in 1896, sold in that year 7 machines; in 1897, 36 machines, and in 1898, 207 machines.

The Morgan-Gardner Electric Pick.

The Morgan-Gardner Electric Company has recently brought out an electric pick-machine which is claimed to be the only successful one on the market. I do not know of any other electric pick-machine that has proved successful. The manufacturers have designed this machine for work in entry-driving, cutting necks and turning rooms or other narrow places in mines having electric installation, when it is difficult to use the chain-machine. The machine has a reciprocating piston actuated by a spring and cam; the spring striking the blow and

Fig. 6.



Sullivan Pick-Machine. (Index Pointer on Rear Head is for Adjusting the Cut-off.)

the cam drawing the piston back. The cam is driven by a motor with a special armature, of the toothed-gramme ring type, with coils wound below the surface. The important feature is the manner of connection of commutator to coils, there being no wire connection at this point, which makes the armature as nearly indestructible as possible.

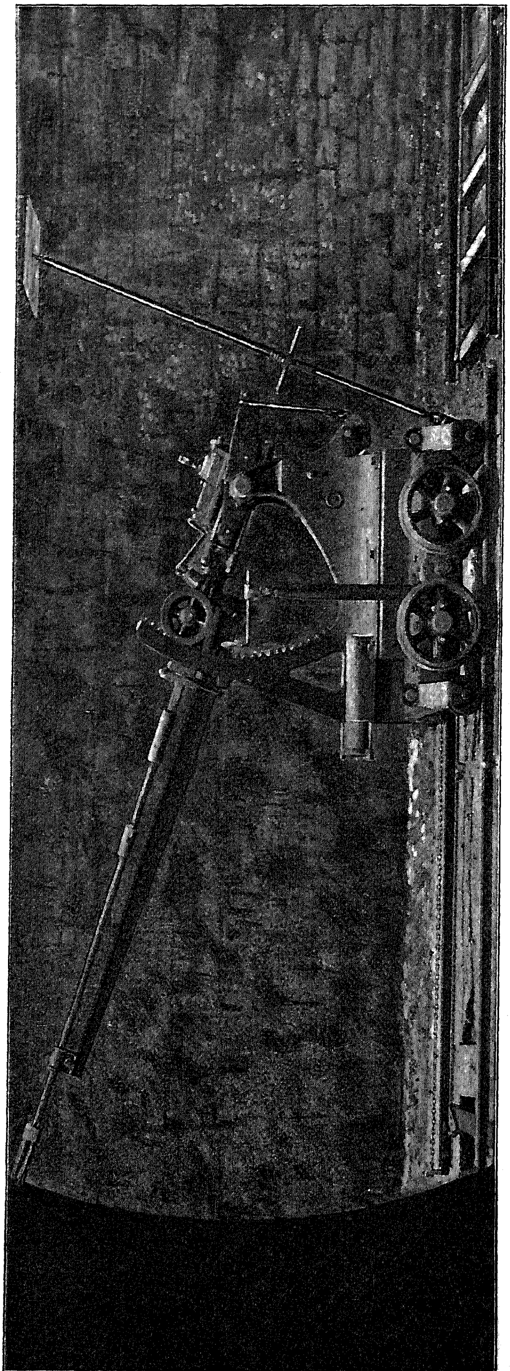
The stroke of piston is 8 inches, and it runs from 175 to 225 strokes per minute. Length of machine, 7 feet; width over wheel, 21 inches; weight, 750 pounds.

The Cutter-Bar Machine.

Although this type of machine may now be considered obsolete, it having been entirely superseded by the chain breast-machine, it possesses a historic interest. Its introduction was almost contemporary with that of the pick-machine and met with similar difficulties. The cutter-bar was the pioneer product of the Jeffrey Manufacturing Company, the first machine having been placed upon the market in 1876. It was designed originally to be operated by compressed air. The engine on this machine was upright, and consisted of two cylinders, solid with the outside frame of the machine; and the part carrying the cutter or bits was fed into the coal by means of a screw working through a movable nut. This nut formed part of the inside frame, or that portion of the machine to which the cutter-bar was attached. The cutter-bar was rotated by means of an endless chain, driven by sprockets attached to the main driving-shaft of the machine. The manufacturers frankly admit that the first machines of this type were crudely constructed, very light and purely experimental. They were put to work, however, and although found to be capable of cutting very soft coal, they quickly went to pieces when they encountered harder bituminous coals, or any of the impurities which are commonly found in bituminous veins. Immense amounts of money and patience were expended on the early type of machine; and the first ones built were kept constantly on the road between the mines and the shop, first one part failing and being strengthened, and then another part giving way.

While the process of strengthening was going on, new features were being developed. The machine was made heavier;

FIG. 7.

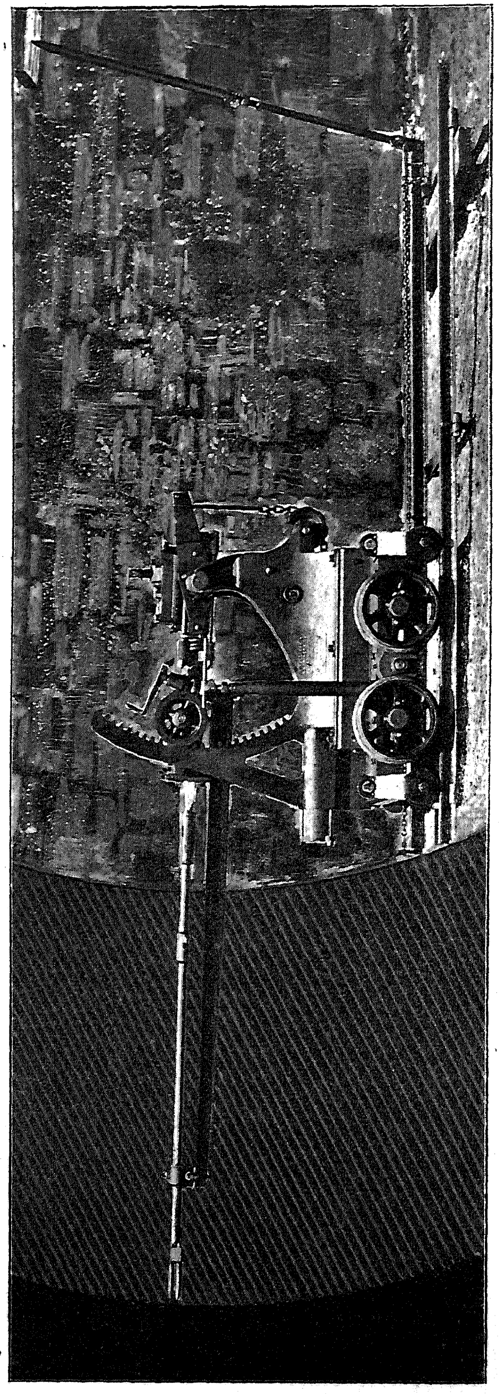


Sullivan Shearing-Machine at Beginning of Cut.

the cylinders were changed from the vertical to the horizontal position, and from the outside or stationary part of the machine to the inside or movable frame, so that the motor moved forward as the cutter was fed into the coal; the feeding-arrangement was changed from the screw-and-nut to the rack-and-pinion type; and so on, until an air-driven cutter-bar machine had been developed which impressed coal-operators favorably. Before this was accomplished, however, a number of the earlier types of air cutter-bar machines had been put to work, and to a degree, successfully; but their field was confined to the very softest coals, in which sulphur (pyrite), clay-veins, etc., were not encountered. Strengthening and improving the machines made it possible to attack harder coals; and in each year after the first machine was built, coal which the year before the builders would have hesitated to attack, has been successfully mined.

Between 1880 and 1890 the engineers of the Jeffrey Company, thus engaged in constant work on the air cutter-bar machine, naturally had their attention called to the possibility of substituting an electric motor for the air-engine on the machine. The officers of the company did not feel that they had had sufficient experience or knowledge in regard to electric motors to design a motor for the trying conditions incident to mining work, so they presented their ideas to two or three of the most prominent electrical concerns at that time, and these concerns sent to the factory their most experienced engineers, who tried to devise a motor which would be practical and efficient on mining-machines. Their efforts were without practical result; and it devolved upon the Jeffrey engineers to design and develop a motor which would be practical for mine use. Many persons thoroughly conversant with coal-mining machinery discouraged the attempt, saying that it was simply throwing away money and wasting power, because an electric motor working in a coal-mine where there was a constant dripping of water from the roof, the bottom was wet and muddy, and there was a terrible dust made by the cutting of the machine, would not prove practical; but it is with a good deal of gratification that the Jeffrey Company is able to point to-day to the very first electric coal-mining machine built by the company, which is cutting coal every day on which the mine in which it is used

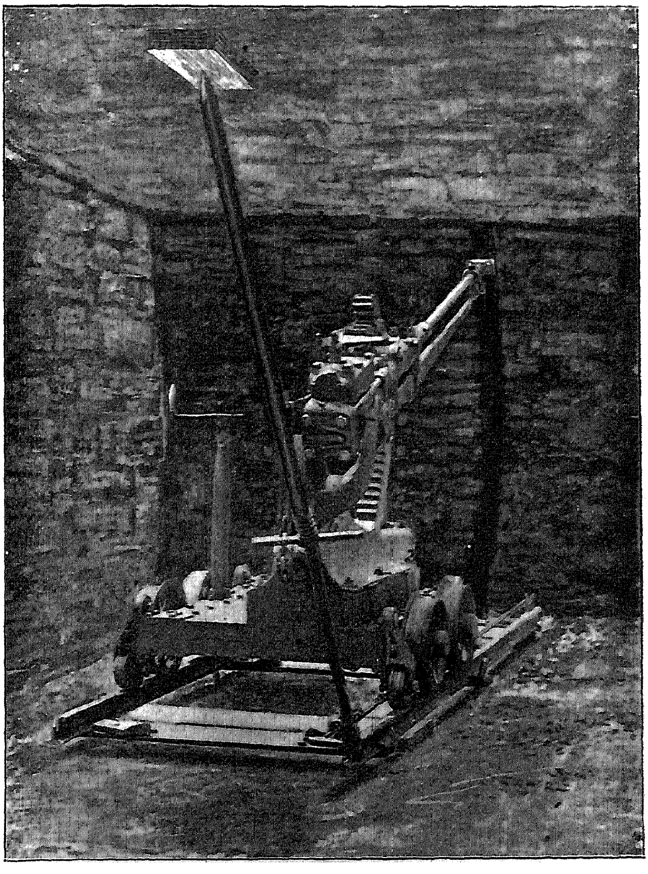
Fig. 8.



Sullivan Shearing-Machine at Completion of Cut.

is running. There was little change made in the mechanical arrangement of the cutter-bar machine when the electric motor was attached to it, but immediately after it had been shown that a cutter-bar machine could be operated successfully by electricity there was an added interest developed all over the

FIG. 9.



Sullivan Shearing-Machine, Showing Character of Cut.

country by mine-owners in mechanical means of getting coal. The electric power recommended itself, at the same time, for other purposes, such as the running of fans, hoists, etc.

In a short time the cutter-bar type of coal-cutter gave place to a still more successful machine. In its time, however, it had done good service, and some of the cutter-bar machines are still

at work. That it is a "back-number" now, however, was proved, to my entire satisfaction at least, when, on my visit to the Jeffrey works a few weeks ago, I was shown, on the scrap

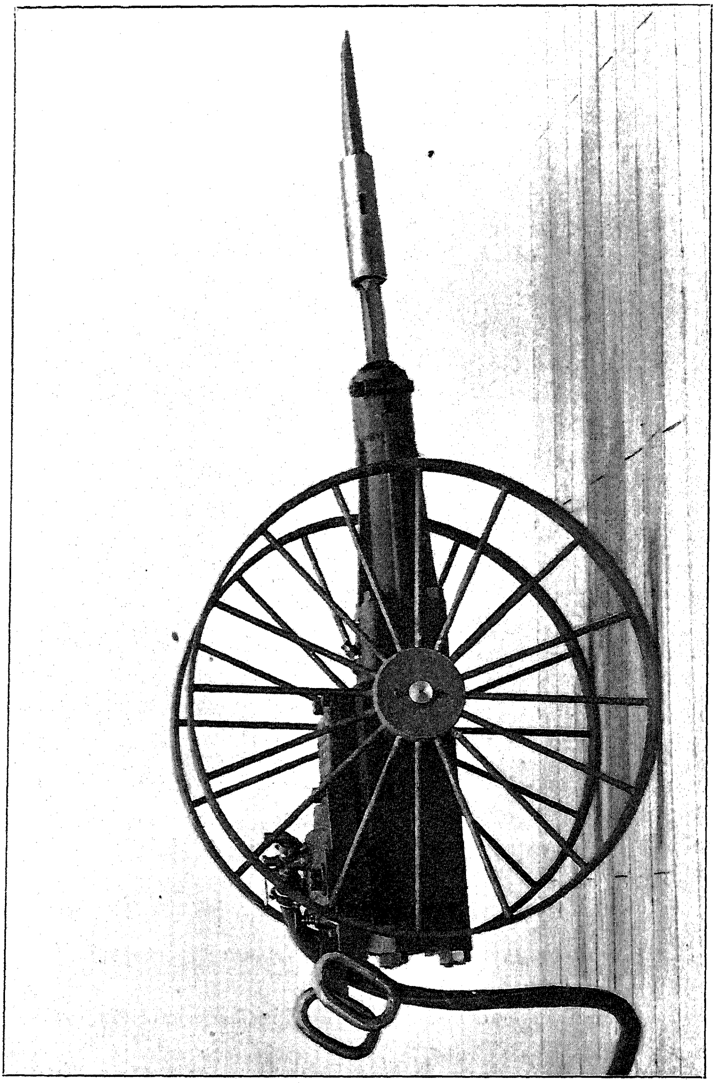


FIG. 10. Sullivan Pick-Machine Mounted for Shearing.

heap, several of these machines that had never been used at all.

The first air-driven cutter-bar machine operated by the upright engine was put to work in 1876. Between 80 and 90 of

these machines were installed before the upright engine gave way to the horizontal type. Then about 450 air-driven cutter-bar machines with horizontal engines were installed. Electricity was first applied to the cutter-bar machine in 1889. The reason of the change from the cutter-bar to the chain was that the latter attacked the coal in a way that required much less power. It was found that each chain-machine would do more work than the cutter-bar, and as less power was required, it was easier on the machine, and repairs were accordingly reduced. Moreover, particles of sulphur which stopped the cutter-bar, and which had to be cut out by hand, could frequently be dragged out by the chain.

The Chain Breast-Machine.

This type of under-cutting machine which now contends for supremacy with the pick- or punching-machine was brought out in 1894; three different companies, the Jeffrey Manufacturing Company, the Link-Belt Machinery Company, and the Morgan-Gardner Electric Company all entering the field in that year. One of the natural results was the commencement of suits and counter-suits for alleged infringement of patents. The litigation was lively, and some points of the controversy are, I believe, still undecided. In general design there is a marked similarity in the machines of the three makers, the difference being in details of construction, which give to each machine its claim to superiority over its competitors. The arrangement of the cutting-device, the endless chain, is practically identical in all three machines.

In the attack upon the coal the cutting-parts operate at right angle to those of the cutter-bar. The chain, with its cutting-bits, is driven, either by compressed air or electricity, as the case may be, at a speed of from 250 to 275 feet per minute; and the movable frame, carrying the chain and the motor, is fed forward at a speed determined by the resistance offered by the coal. The rear end of the machine is securely held in place by means of a jack, set to the roof, while the forward end is secured by a jack set at an angle of about 45° into the face of the coal. The forward jack is placed at this angle in order to overcome the tendency of the machine to be forced sideways as the chain cuts the coal.

One of the most notable, and, so far, practically the final step in the development of a successful mining-machine was made when the chain-machines were brought out. The speed with which one of these machines will do its work seems almost incredible. An average of five minutes, after the machine is in position, required to make a cut 6 feet deep, 44 inches wide and 4½ or 5 inches high, and to withdraw the cutting-frame, is the ordinary measure of the effectiveness of this type. A record of 1700 square feet of cutting in nine and a half hours is claimed for one of these machines. This would mean about seven and a half minutes to each cut 6 feet deep and 44 inches wide, including the moving and setting of the machine. This record must have been in a competitive test; for my observation has been that more time is taken in moving and setting the machine than in making the cut.

All of these machines are supplied with an automatic cut-off which stops the machine when it has reached the end of its travel, either forward or backward. The return-travel is made in about one-fourth the time required to make the cut.

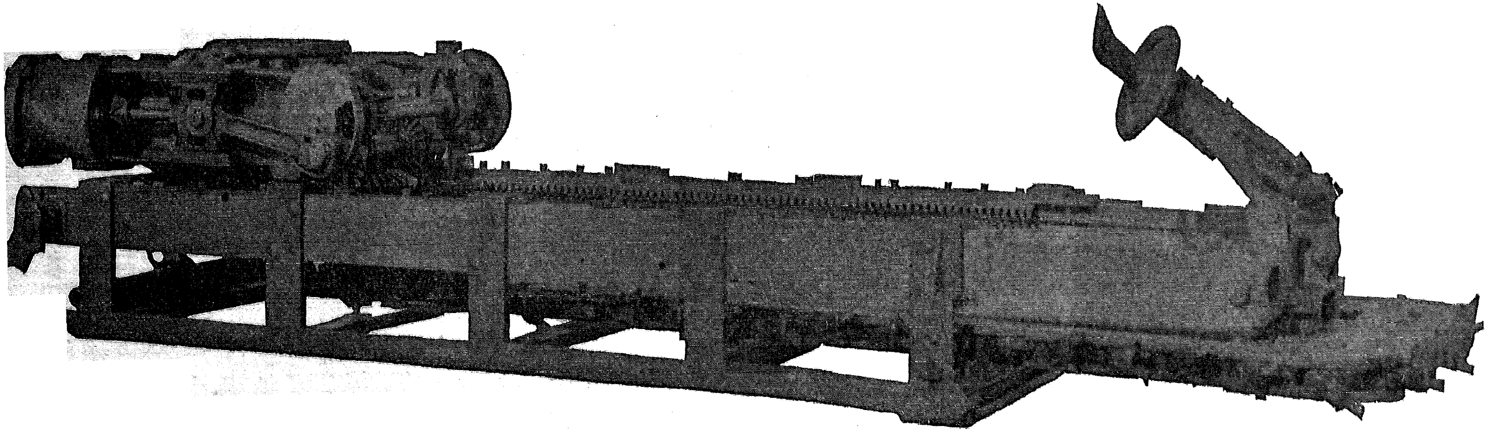
Mention has been made of some of the advantages possessed by the pick-machine. The chain-machine bases its claims upon the rapidity with which it does its work, the very small amount of slack coal made in the cutting, and the fact that the runner is not subjected to the racking action of the pick-machine. I have noticed, however, what appeared to me one element of danger in the electric installation, and that is that, except in the rooms where the machine was at work, the wires were naked. A slip or stumble might easily cause one to fall against or grasp a live wire with serious, if not fatal, result. It is amusing to observe the care the mules take to avoid coming in contact with that line of copper running along the sides of the entries.

The following descriptions of the different chain breast-machines have been furnished by officers of manufacturing companies:

The Jeffrey Chain Breast-Machine.

The introduction of the chain coal-cutter was a radical improvement, doing away, as it did, with the cutter-bar, and with numerous chains which it was necessary to use in connection therewith, namely, the main driving-chain for the cutter-bar, the

Fig. 11.

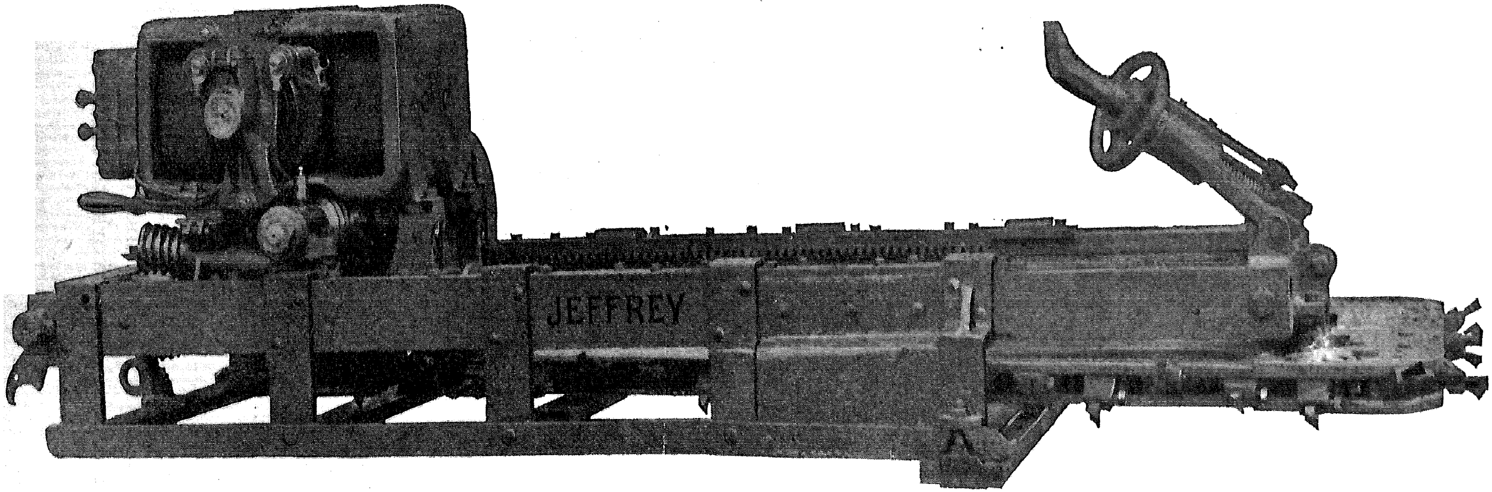


Jeffrey Air Chain-Machine, Horizontal Cylinders.

slack- or cleaner-chains on the outside of the frame, which were used to remove the cuttings or slack, and the driving-chain used to operate the main slack-chain shaft. The outside frame, or stationary part of the apparatus, was in this chain-machine very similar to the outside frame of the cutter-bar type; the greatest change having been made in the inside or movable cutter-frame. This was reduced to a simple and compact construction, consisting of an isosceles-triangular frame, the equal sides of which were about twice as long as the third side. At the small angle was located a driving-sprocket, to which the power was given; and at each one of the other angles an idle wheel or sprocket was located. About this triangular frame, in suitably arranged guides, was placed an endless chain of links, each of which was recessed to receive a bit or cutter. By means of the main driving-sprocket this cutting-chain was carried around through the guides of the triangular frame with a very small amount of friction. At the point in the triangular frame where the driving-sprocket was located, the frame was properly attached to the main carriage or bed of the electric motor or air-engine, whichever was the motive power. This whole inside frame, with its motor and bed, was moved forward by rack-and-pinion gearing in the outside or stationary frame, while the chain with its cutter was being moved through the guides of the inside frame at a speed of about 250 feet per minute. The forward travel of this inside frame, with other moving parts, was so arranged that a machine with a cutting- or inside-frame that would bear under the coal in a cut 6 feet deep and 44 inches wide, would make a full cut in about three and one-half minutes. The return travel of the moving parts was much more rapid, so that the entire time consumed in feeding to the full depth and drawing out again was about four and one-half minutes. By means of this chain-machine the coal was attacked, as above stated, in a direction at right angles to that of the cutter-bar machine; and this proved to be an easier and more natural method, [illegible] much less power. Moreover, coal which had been formerly considered too full of impurities and too hard to be cut with the cutter-bar machine was now successfully cut with the chain-machine.

The general features of this first type of chain-cutter have been followed out in subsequent machines, and the machine of

Fig. 12.



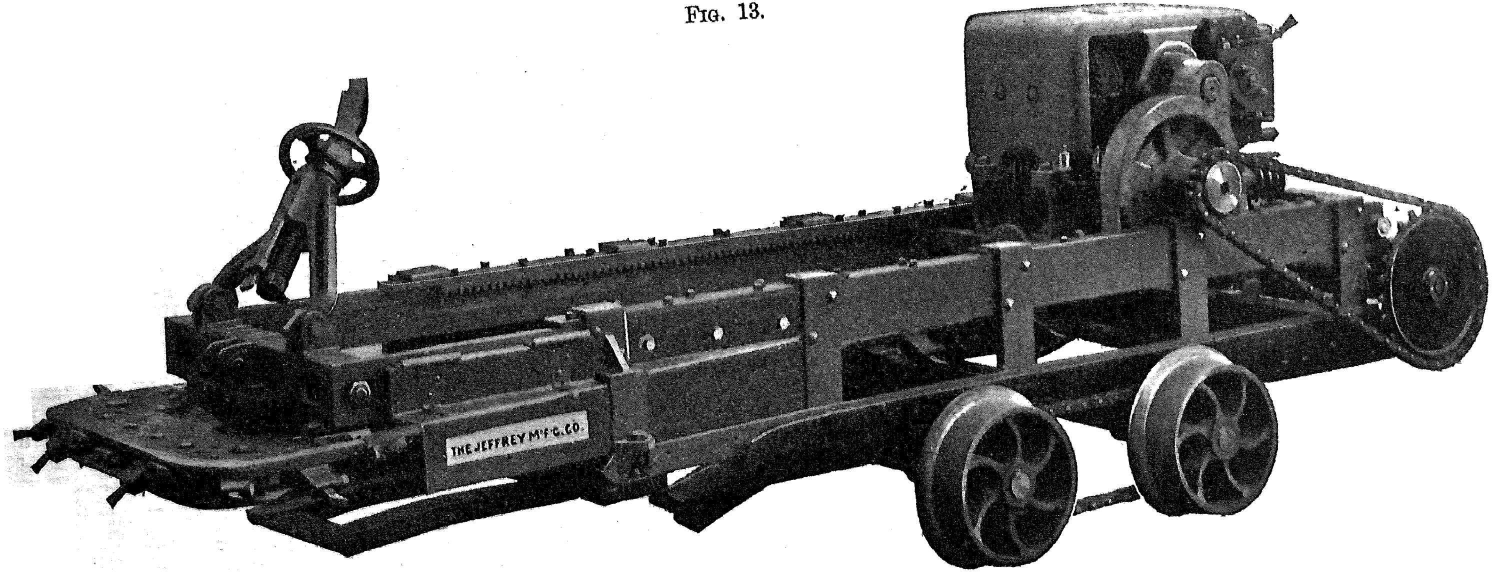
Jeffrey Electric Chain Cutting-Machine.

to-day is, in general design, much like the earliest one. Changes have been made, of course, in details and dimensions, suggested by experience as required to increase the capacity of the machine or diminish the liability to delays and expense through the breaking of parts. The chain-cutter is designed for use in the rooms and entries of mines where the coal runs 30 inches and over in height and where there is no dip or pitch in the vein of more than 8° to 12° from the horizontal. The capacity of this machine is very largely dependent upon the thickness of the vein in which it is used, the nature of the coal and the width of the rooms. It has a record, however, of cutting in nine and a half hours, when operated by two men, a machine-runner and a helper, 1700 square feet of coal. The saving produced by the use of this machine also depends very largely on the local conditions, the mining-scale, and the care which the plant receives at the hands of those in charge of it. The saving in actual figures, however, has never, to the knowledge of the builders, run below 5 cents per ton as compared with pick-mining, and this only under the most unfavorable conditions; while some records furnished by users of the machine show savings amounting to 31½ cents per ton.

The Jeffrey Company states that this type of machine is used in every coal-producing country in the world and is the most universally used of the types manufactured by this company, for which reason more space has been given to its description than to the several other types which they are building. The other types are known as the long-wall and shearing-machines.

The shearing-machine was designed for making vertical cuts in the coal. It resembles very closely the chain coal-cutter with the cutting-frame at right angles to its normal position. There has been a demand for this machine in districts where the coal does not have well-defined faces and where it was found more advantageous to shoot the coal down from the solid. Mr. R. Grosvenor Hutchins, Vice-President of the Jeffrey Company, says they have had the experience of all manufacturers who bring out a new machine which is a departure from the commonly accepted plan, and that this shearing-machine will require some missionary work to create a field for its use.

Fig. 13.



Jeffrey Electric Chain-Machine on Self-Propelling Truck.

The Link-Belt or "Independent" Machine.

The Link-Belt Machinery Company of Chicago began the manufacture of mining-machines in 1889. The early patterns of the machines made by this company have been entirely discarded and the active introduction of its machines may be said to have commenced in 1894, when the Link-Belt chain breast-machine was placed upon the market. I am reliably informed by operators who have used them, that the Sperry long-wall machine was made by this concern, and that its abandonment was due to the comparatively insignificant amount of long-wall mining practiced in this country and the consequent limited field for its use, which rendered its manufacture unprofitable. In fact, I was told by an official of one of the largest companies operating on the long-wall system in some of the thin seams in Kansas and Missouri, and who finds the Sperry machine well adapted to the peculiar local conditions that obtain there, that, some time since, an order was forwarded for two additional machines, but the manufacturing company did not care to take the order, as it had stopped making that machine. The coal-company then bought the patterns and had the machines built.

The first chain breast-machine built by the Link-Belt Company was, as previously stated, constructed in 1894. This company, like the others, has not been able to secure a statement of the tonnage won by the machines since they were installed. There are three features of this machine which present themselves readily to the observer. The first is in the style of the motor, which is entirely different in shape to the others shown. The second is the rollers placed at the rear and heavier end of the machine to facilitate moving it along the face of the coal, and the third is the low frame, and the fact that none of the frame is to be observed below the cutting-chain. The forward end of the machine rests upon a shoe, placed just below the jack, in the center of the forward end. This shoe is even with the lowest row of cutting-teeth, and consequently level with the under-side of the cut in the coal.

The following description of the Link-Belt chain-machine has been furnished by Mr. H. E. Goodman, manager of the mining department of the Link-Belt Company:

The "Link-Belt" Electric Chain Breast-Machine is made for a depth of undercut of 5, 6 or 7 feet, as desired, and a width of cut of from 36 to 48 inches. The

height of the kerf cut by the endless chain-cutter is from 4 to 5 inches. The machine is operated by a 20 H. P. dust- and water-proof iron-clad multi-polar motor of the latest type. The armature shaft is longitudinal with the machine,

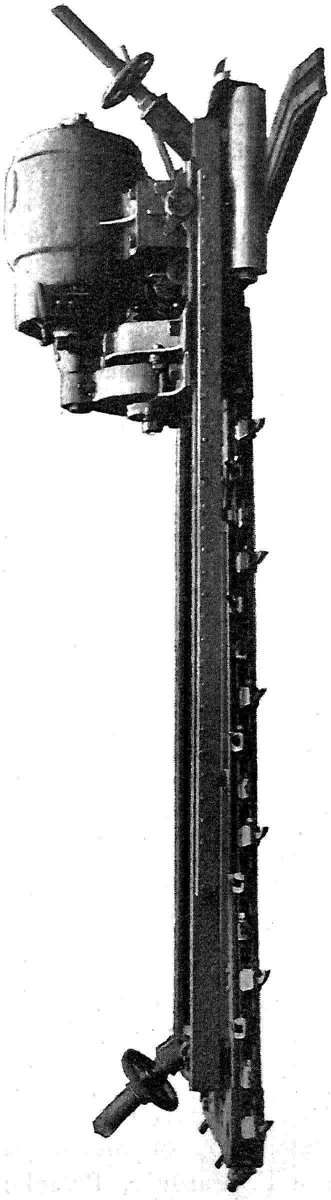


FIG. 14. "Independent" or "Link-Belt" Electric Chain-Machine.

on the front end of which is keyed a cut spur pinion of forged steel $3\frac{1}{2}$ inches in diameter and having a 3-inch face. This meshes into an intermediate gear of steel, with cut teeth $14\frac{1}{2}$ inches in diameter and with a 3-inch face. A forged

steel bevel pinion, also with cut teeth, is keyed rigidly to this intermediate gear, and meshes into a cast-steel bevel gear with cut teeth. This bevel gear is attached to a sleeve which revolves on a vertical shaft, the main driving-sprocket which actuates the cutting chain being keyed to the lower end of this sleeve. With the armature in a horizontal position, this train of gearing constitutes the simplest possible means of accomplishing the reduction in speed between the armature and main driving-sprocket. On the sleeve to which the driving-sprocket is fastened is placed a forged steel worm, which meshes into a bronze worm gear, and is the basis of the feeding mechanism. This worm gear is mounted on a shaft placed at right angles to the main frame of the machine. Two steel gears are also mounted on this shaft, one meshing into an internal gear mounted on a second parallel shaft for feeding the machine under the coal, and the other meshing into an external gear, also mounted on this second shaft for returning the machine at the completion of the cut. These gears are so arranged that the machine is fed backward about five times faster than forward. Mounted on the ends of this second shaft are two steel sprocket wheels which mesh into the pin rack, which is a part of the stationary frame. When these sprockets are revolving, the machine is fed forward or backward. The system of clutches is so arranged that by throwing the lever to right or left these sprockets are engaged, and the machine is fed forward, backward, or stopped at the will of the operator. Positive stops are provided for automatically stopping the machine at each end of the stroke. When the machine is ready for operation, the stationary frame is securely fastened in place against the face of the coal and roof by means of front and rear jacks. By means of a system of rollers the rear or heavy end is easily moved across the room or entry with slight effort on the part of the machine runner. These rollers are automatically securely locked when rear jack is set. The construction of the machine with the traveling frame underneath the stationary frame keeps the chain practically level and close to the bottom, thus leaving little, if any, bottom coal to be taken up by the loaders, a result not possible with any form of machine having the traveling frame above any part of the stationary frame.

A suitable truck of the same gauge as the mine-track is provided, on which the machine is placed at the completion of work in any given place, and hauled by a mule to another section of the mine. Where grades are excessive, a power truck is furnished, by means of which the armature shaft of the motor is geared to the truck wheels, the machine in this way propelling itself through the mine entries and up the road-ways of the rooms to the face of the coal. The cutting-chain is in all cases thrown out of gear when the power truck is in use.

The Morgan-Gardner Machine.

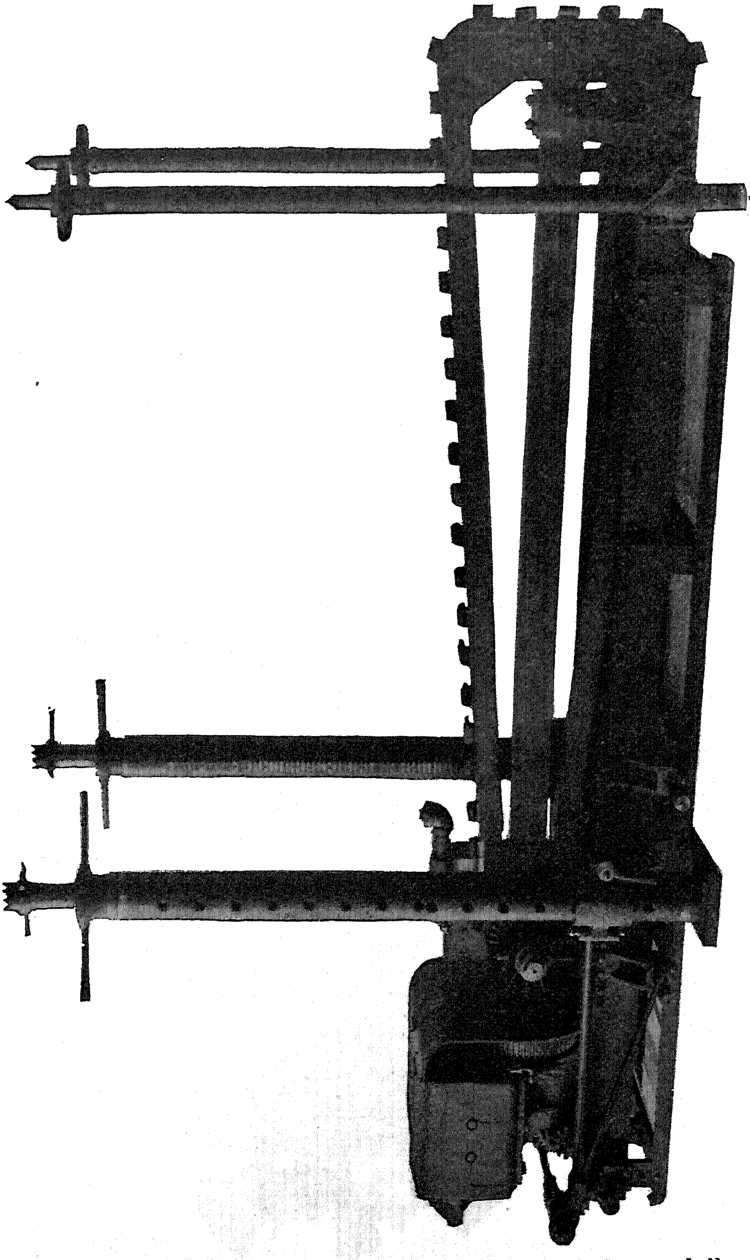
The Morgan-Gardner Electric Company, of Chicago, began making chain breast-machines in 1894. In that year the company shipped 20 machines. In 1895 it shipped 75; in 1896, 190; in 1897, 165; and in 1898, 120 machines.

The following description of this machine has been furnished by Mr. James P. Gardner, President of the Morgan-Gardner Company:

The machine weighs 2400 pounds, and will run in the full depth in 4½ minutes and back in 45 seconds. This speed can be increased to 3½ minutes and 30 seconds backing out, according to quality of coal.

The total length of the 6-foot cutting-machine over all is 10 feet. The height is 29 inches over all. The width across the machine at cutter head is 42 inches

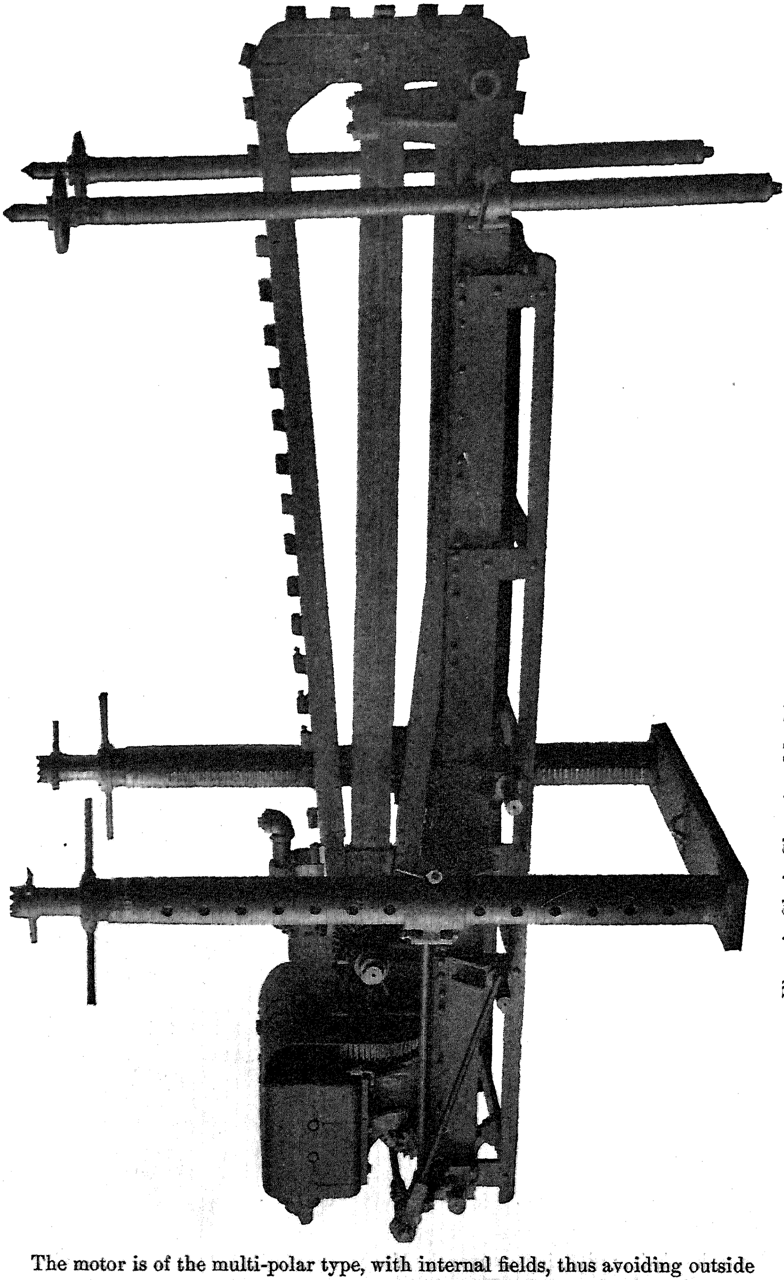
Fig. 15.



Electric Shearing-Machine in Position.

over the chain and 45 inches over the bits, thus giving full 42-inch cut, and allowing lap into previous cuts. The width across the frame is 24 inches. This enables the machine to be loaded on a truck that will run on a 28-inch gauge of

track without making a special truck, and still less gauge by making special truck.



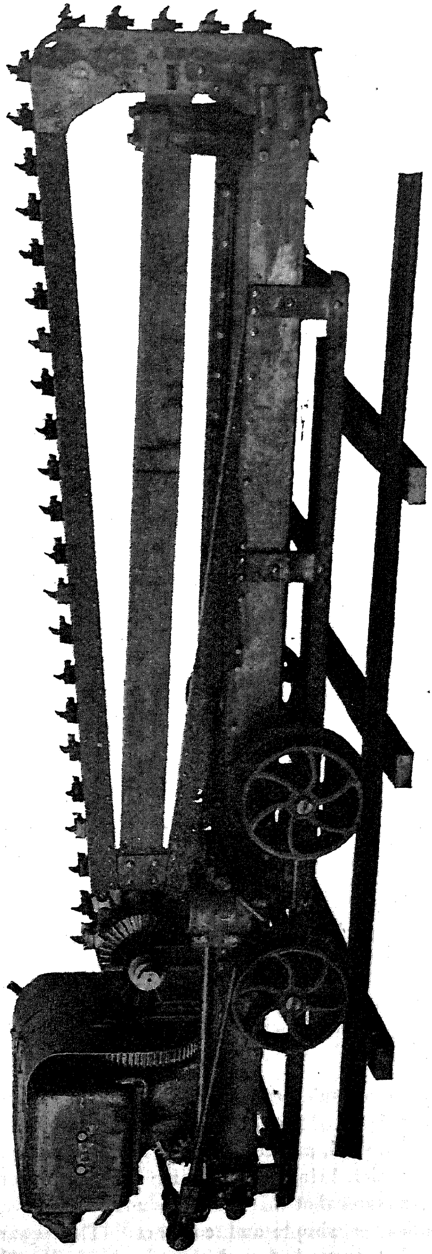
Electric Chain Shearing-Machine. Is Raised and Lowered by its Own Power.

The motor is of the multi-polar type, with internal fields, thus avoiding outside magnetism. This type of motor is very compact, and also easy to get at.

The armature is of the toothed gramme-ring type, with the coils wound in slots

below the surface of the armature, thus protecting them from danger by rough usage. Mr. Gardner states that the company has never had any of this style of

FIG. 17.



Electric Chain Shearing-Machine on Truck.

armatures burnt out. The field coils are wound on spools that slip over the pole-pieces, and can be readily removed.

The gears are all made from steel, with teeth cut out of the solid. The fact

that the armatures run on end does away with bevel gears, and greatly simplifies the gearing, as all the gears are plain spur gears, and there is only one worm wheel.

It is claimed that the gears or shafts on this machine are less in number than are to be found on any chain-machine made at the present time. The chain is of the up-down-and-center link style, all the bits being straight and of the same length, economizing time in dressing and replacing.

The machines are so constructed that both machine-runner and helper can work at inserting bits at the same time. There are 48 bits in a chain of 6-foot under-cut. The materials used in construction are cast- and wrought-steel throughout, with the exception of a very small amount of cast-iron, which is used where strength is not required.

It is also claimed that less amperes of current are used per width of cut than in any other machine built. There is an automatic throw-out both in front and back, which enables the miner to make full-length cuts without danger of breaking anything. A break washer, or safety washer, adds additional security against accidental breaking.

The speed of travel of chain is 275 feet per minute. The number of revolutions of armature per minute is 750, with 220 volts at the machine.

This company has also recently placed upon the market an electric pick-machine, which has been briefly described above, in connection with the air pick-machines.

The chain breast-machine is converted into a shearing-machine by being turned over on its side. It is then supported on stanchions, and is raised or lowered by the electric power of its own motor. It is especially adapted for entry-driving, turning room-necks, or for shearing, when the coal may be shot from the solid.

The Morgan Standard Machine.

The Morgan Standard Company of Chicago is a new company, engaged in the manufacture of chain-machines. Mr. E. C. Morgan secured patents on a chain breast-machine which is claimed to have valuable features distinctively its own, and to do away with objectionable features developed in earlier types. It is described by Mr. Morgan as follows:

The stationary frame on which the motor and cutting mechanism slides consists of a rectangular forging of $2\frac{1}{2}$-inch steel. Into this frame is fastened a single rack made of cold rolled steel, and the feeding is accomplished by an ingenious piece of mechanism, which brings the feeding pressure exactly in the center of the cut. Mr. Morgan states that this feature is not found in any other machine.

The feed mechanism is simple and compact. The square-jawed clutch is placed on the worm shaft instead of on the worm gear shaft. This gives it greater leverage, therefore it throws easily. The clutch is thrown automatically when the machine reaches the end of the feed at front and rear. The cutter-head is

firmly bolted to the center bar and side bars, and the side bars are riveted to the center bar at the rear, thus making a very strong frame. The holder for preventing lateral movement is of improved construction, and can be replaced at small expense when worn. The feed shaft is provided with an improved safety device, which prevents the feeding mechanism being broken when the cutter frame gets caught, from any cause. The motor is a powerful one and is claimed to stand a 50-per cent. overload for a long time. The commutator is large, allowing only 30 amperes per square inch of brush area. The motor is wound for either 250 or 500 volts, as desired. The oiling devices have received careful attention. The improved construction at upper bearing on armature shaft prevents any oil getting into the motor. The machine makes a cut 6 feet deep and 45 inches wide in four minutes. Three minutes for feeding in and one minute for drawing out; and either 5 or 7 feet under-cut will be furnished when desired, and the speed of either feed can be changed at any time at slight expense. The machine is furnished with any speed of feed desired without extra charge.

The General Electric Company of Schenectady, N. Y., have made a few machines of the chain breast-pattern, but the profits on the business were not sufficient to warrant the continuance of their manufacture, and they have retired from this line of business.

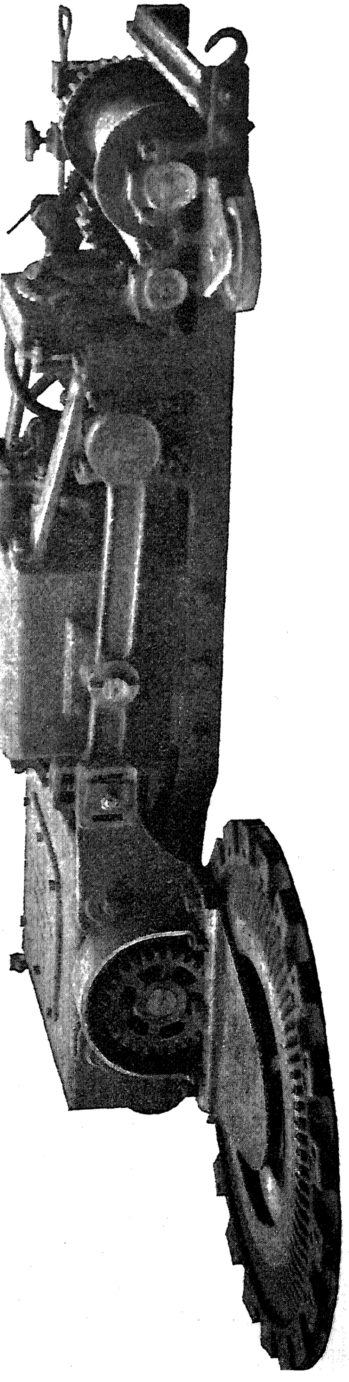
The Long-Wall Machines.

I have already referred to the passing of the Sperry long-wall machine, still used to a limited degree in some of the thin veins of the Western States. While it is true that the chain-breast and the pick-machine suit practice in this country, there has been sufficient demand for long-wall machines to cause the Jeffrey Manufacturing Company to devise a practical machine of this type and to engage somewhat extensively in its manufacture. The Sullivan Machinery Company also is bringing out a new long-wall machine; but as the experimental stage is not yet passed, the company is not prepared to furnish information for publication and discussion.

The long-wall machines have been developed within the past few years, and their application *in this country* is somewhat limited on account of the scarcity of mines having local conditions suitable to their application, and also because the pillar-and-room is the prevalent system in the United States. The long-wall machine is being generally adopted in foreign countries where that system of mining is in greater favor than in this country; and most of the machines are built for export.

The Jeffrey long-wall machine consists of two distinct parts, the motor and feeding-gear on its frame, and the cutter-wheel.

Fig. 18.



Jeffrey Electric Long-Wall Machine.

It has a rectangular frame, with drum, located at one end, upon which mechanically winds the wire rope used in moving the machine along the long-wall faces. The motors or compressed-air engines are located in the middle of the rectangular frame and furnish the power for the train of gears at the rear end. Projecting from the rear end of the machine is a disk or cutter-wheel of such diameter that it extends beyond the side of the main body of the machine to the depth that it is desired to under-cut the coal. These machines are being used to-day to under-cut to depths of 3, 4 and 5 feet. In the periphery of the cutter-wheel are recesses, into which are placed the cutter or bits. The main points of advantage claimed for this type of long-wall machine, outside of the powerful construction and enormous capacity of the machine, are: the tilting device for the cutter-wheel, by means of which it is possible, while the machine is at work in the coal, to move the cutter-wheel in order to follow any unevenness in the floor of the mine or cut over or under any foreign substances that may be met with; and the device for altering the speed of travel of the machine along the face of the coal while the machine is in operation. By this latter mechanism, three different speeds may be obtained without stopping or slowing down the machine at all. This machine also requires only one rail upon which to operate, which makes it much easier for the operator to keep the track laid in front of the machine, without having to stop, as is the case where two rails are laid. This single rail is held in place by means of suitable jacks. It has been very difficult to get positive data as to the results obtained by the use of this machine. Companies which have adopted it seem to hesitate to give information, for no other reason, so far as can be seen, than that they are getting very satisfactory results and wish to keep the benefit entirely to themselves. This is the reason assigned by the manufacturers. The operators will not indicate, either through letters or by personal interviews, that they are getting any satisfactory results whatever. Tests made by the Jeffrey Company have demonstrated the capacity of the machine to cut from 500 to 800 linear feet of face per day. The capacity, of course, depends upon the length of the face, the height of the coal and the evenness of the floor.

The Stanley Entry-Driving Machine.

This machine, like the cutter-bar, has passed away. It was the invention of an Englishman, Reginald Stanley, and about ten machines were built in this country by the Sullivan Machinery Company. Where it was desired to drive single entries rapidly it served its purpose well; but where it was desired to advance all the entries at about the same rate, the machine was a failure, as it was too cumbersome to move about. The machine cuts a circular entry, or in reality cuts a tunnel through the coal, the fine coal from the cutting being carried by a conveyor, which is a part of the machine, to a car back of it. The best record made by this machine in this country was 35 linear feet in a shift of ten hours, cutting a 7-foot tunnel through coking-coal.

Some Patent Office History.

As previously stated, the first patent on a coal-cutting machine issued by the United Sates Patent Office was in 1858 to Elisha Simkins, of Allegheny, Pa. (No. 21,908.) From that time until 1876 many patents were issued on various devices for cutting coal, but I have been unable to discover evidence of any of them having survived, or having been proved economically successful. Patent No. 144,529 was issued November 11, 1873, to two Englishmen, John Gillott and Peter Copley, on a machine embracing the principal of a cutting-wheel or disk extending from the side of motor-carriage, which moved on double tracks along the face of the coal. I can find no evidence of one of these machines having been installed in the United States.

Out of the, approximately, half-thousand patents which have been issued on mining-machines, I have selected the following as possessing the greatest interest in leading up to the present development, although many of the earlier, and in themselves unsuccessful and useless inventions, were important steps in the evolution. One invention consisted of a heavy open framework of wood timbers in which were swung parallel beams acting upon the principle of a battering-ram. The coal was intended to be cut by a series of teeth arranged along a bar at the forward end of the ram and joining the swinging beams.

The upper timbers of the framework were notched so that the bar from which the ram was suspended could be moved forward as the cut was deepened. The ram was to be operated by the miner.

Patent No. 155,593 was issued October 6, 1874, to Porter Sheldon, of Jamestown, N. Y. It embraced the principle of the cutting-bar but was not entirely successful.

No. 179,464, issued to Treat T. Prosser, of Chicago, Ill., on July 4, 1876. This consisted of an endless cutter-chain supported by an arm extending from the forward end of the machine and which swung upon a pivot, so that crescent-shaped cuts were made as the cutting-parts moved forward. The machine was mounted on a four-wheeled carriage which rested upon tracks the ends of which were brought close up to the face of the coal. A circular track on the carriage allowed the machine to be revolved so that the cutting could be made in any direction. So far as I can see, the cut made by this machine must have been at least a foot above the floor on which the track was laid. The motive-power was compressed air.*

No. 172,637, issued to F. M. Lechner, of Waynesburg, Ohio, on January 25, 1876, was on the original cutter-bar machine which later became the product of the Jeffrey Manufacturing Company—Lechner assigning to the Lechner Mining-Machine Company, which was succeeded by the Jeffrey Company. Patent No. 299,655, issued to Benjamin A. Legg on June 3, 1884, consisted of certain improvements on the cutter-bar, and these also became the property of the Jeffrey Company. Legg applied for patents on additional improvements on the same machine in 1885, which were granted in 1894. No. 524,064, and other improvements invented by Henry B. Dierdorff (for which patents were applied for in 1892 and granted in Patent No. 574,402, January 5, 1897), were also added to this machine, having become by assignment the property of the Jeffrey Company. Patent No. 585,018, issued in June, 1897, to H. H. Bliss, of Washington, D. C., was on improvements on the cutter-bar machine, but this type of machine had by that time become obsolete.

* It may be that this is the "Monitor" machine referred to by Dr. Raymond at the New York meeting, where the illustrated abstract of this paper was presented.

The intermediate between the cutter-bar and the chain breast-machine was marked by an invention patented by Dierdorff and assigned to Jos. A. Jeffrey, of the Jeffrey Manufacturing Company (applied for in 1886, issued April 23, 1895, No. 538,210). It consisted of two half-disks set in juxtaposition at the forward end of the machine which were oscillated by a common piston-rod, the cutting being accomplished by saw-teeth or cutting-bits set in the periphery of the wheel.

In the meantime J. W. Harrison, of Adrian, Mich., had taken out Patents Nos. 321,103 and 391,707 on inventions for cutting the coal with bits set in a bar and given a reciprocating motion as of sawing, while Patents Nos. 342,614 and 347,813 were issued to B. A. Legg in 1886 for a reciprocating bar-machine having saw-teeth cutters.

Patent No. 198,610, issued to J. W. Harrison on December 25, 1877, was on the original invention of pick-machines. No. 219,090 was issued to the same party for sundry improvements on the same machine on September 2, 1879, and a number of other patents were subsequently issued on the same machine. Benhard Yoch was granted a patent (No. 242,734) on June 7, 1881, on a pick-machine of somewhat different type, and Patent No. 253,747 was granted to Thomas Murray, of St. Louis, Mo., February 14, 1882, on a compressed air pick-machine. No. 400,809 was issued April 2, 1889, to C. J. Van Depoele, of Lynn, Mass. Nos. 454,500 and 459,596 were issued in 1891 to E. A. Sperry, of Chicago, Ill., and No. 458,184 in the same year to E. C. Morgan, of the same place, on electric pick-machines.

In October, 1883, patent No. 287,032 was issued to Samuel C. Lechner, of Columbus, Ohio, for a chain breast-machine possessing improvements on an invention for which a patent was applied for by Van Amburg Lechner in March of the same year. In these machines the cutting was intended to be accomplished by bits set in two endless chains operated in opposite directions, using compressed air as the motive power. Patent No. 340,791 was issued to Van Amburg Lechner and S. C. Lechner on April 27, 1886, for improvements on their previous inventions. They assigned a two-thirds interest to F. M. Lechner, of Columbus. In July, 1890, patent No. 432,754 was issued to F. M. Lechner on a single-chain machine. He

assigned his interest to the Lechner Electric Mining-Machine Company. Patent No. 503,607 was also issued to F. M. Lechner in August, 1893. No. 548,970 was issued to Henry B. Dierdorff, of Columbus, Ohio, for improvements on Legg's patent No. 342,614, and applied to a chain-machine. From the foregoing inventions the present Jeffrey chain-machine has been finally evolved.

Patent No. 583,406 was issued May 25, 1897 (re-issued August 10, 1897), to C. E. Davis, of Chicago, and No. 583,409 to F. N. Slade, also of Chicago, and also on May 25, 1897. Both of these assigned their interests to the Independent Electric Company, and from these the "Independent" chain breast-machine, now built by the Link-Belt Machinery Company, of Chicago, has been developed.

Patent No. 574,822 was issued January 5, 1897, on the invention of Edward P. Rauscher, of Chicago, and assigned to the Morgan-Gardner Electric Company of the same place. The principal features of the invention were:

> "To provide devices for protecting the machinery from breaking under an unusual strain, for automatically reversing the feed when the cutting mechanism has reached the limit of its movement into the coal, and for automatically stopping the feed at the end of the return movement."

Patent No. 597,085 was issued to Edmund C. Morgan, of Chicago, January 11, 1898, and is one of the latest issued by the Patent Office. The machine covered by it is built by the Morgan Standard Company.

Patents Nos. 345,551, July 13, 1886; 476,836, June 14, 1892; 524,149, August 7, 1894, and 577,331, February 16, 1897, were issued to Reginald Stanley, of Nimeton, England, on what is known as the Stanley entry-driving or tunneling-machine.

Patents Nos. 412,262 (October 8, 1889) and 435,426 (September 2, 1890) were issued to John Kangley, of Streator, Ill., for a long-wall machine having an arm extending from the side (at the rear end). The arm supported a sprocket-wheel carrying an endless-chain fitted with cutting-bits. No. 550,944 was issued to William J. E. Carr, of Leavenworth, Kansas, on December 10, 1895, on a long-wall machine having the cutting-bits set in the periphery of a disk or wheel. No. 563,776,

dated July 14, 1896, was issued to James E., David A. and Thomas E. Lee for a long-wall machine having the cutting-bits set in a rotating-bar, the bits following the line of the screw-thread so that they acted as a screw-conveyor in clearing the cut of the fine coal made in the cutting.

The foregoing are given as simply showing some of the steps made in developing the machines in use at present. I have not attempted to give the patent specifications in detail, as such a description would not describe the present machines. Many features covered by the patents are common to all the machines of similar type, while some changes and improvements have been made, and new features added of which no records have been made in the Patent Office.

Postscript.

Since preparing the above paper I have completed the statistics of the machine-mining of coal for 1898, and the results, as compiled for the report of the U. S. Geological Survey, are shown in the table given below.

In the statistics for 1897 two corrections have been made, reducing the number of machines used in that year from 1988 to 1956; the number of machines having been incorrectly reported by two firms, one in Iowa and one in Virginia. The total tonnage mined by machines, however, was correctly reported.

The figures for 1898 show an increase even more noticeable than that of 1897 over 1896, particularly in the amount of coal won by machines, which increased from 22,649,220 tons in 1897 to 32,413,144 tons in 1898, a gain of 9,763,924 tons, or a little more than 1.5 times the increase of 1897 over 1896, and 95 per cent. of the total increase in the five years from 1891 to 1896. The number of machines in use in 1898 was 2622 as compared with 1956 in 1897, an increase of 666, or 34 per cent. The number of firms using machines increased from 211 to 287, or 36 per cent. The average number of tons mined by each machine was 11,572 in 1897, and 12,362 in 1898, an increase of 6.8 per cent. in the average actual work, and therefore, presumably, in the effective normal capacity of each machine.

There is scarcely room to doubt that this great increase in

the production of coal by machinery has been the direct cause of the general decline in prices which took place in 1898, notwithstanding the fact that, with a few exceptions, due to local causes, the demand for bituminous coal for 1898 was, at least for the greater part of the year, in excess of the supply, and operators were in many cases throughout the year unable to keep up with their orders. Nor was this unusual demand for coal due in any appreciable degree to the extraordinarily cold winter of 1898–99. Demand for fuel was steady throughout the entire summer of 1898, reflecting the revival which prevailed in the iron and steel, and other manufacturing industries during the year.

Considering the statistics by States, it is seen that machines were introduced into the mines of two States not previously reported, Michigan and New Mexico, the former having 7 machines which produced 1456 tons (the machines having been installed late in the year), and the latter having 29 machines which produced 163,849 tons. No report has been received from the company operating in Alaska, and this Territory is excluded from the tabulation of 1898, so that the total number of States and Territories using machines last year was 21 as compared with 20 in 1897, 16 in 1896, and 8 in 1891. The most remarkable increase in the number of machines in use and in the tonnage won by machines was in Pennsylvania, where the number of firms using machines increased practically 50 per cent., from 64 in 1897 to 98 in 1898. The number of machines in use increased 55.5 per cent., from 690 to 1073, while the product won by machines increased from 8,925,293 tons in 1897 to 16,512,480 tons in 1898, a gain of 7,587,187 tons, or 85 per cent. This increase in 1898 was nearly 2.7 times the increase from 1896 to 1897, and one-third more than the increase in the five years from 1891 to 1896. Pennsylvania's machine-mined product in 1898 was a little over 25 per cent., as against 16.35 per cent. in 1897 and 12.29 per cent. in 1896, of the total bituminous product of that State. In Ohio, where the increase in the use of mining machines was next in amount to that of Pennsylvania, the machine-mined product in 1898 amounted to 5,191,375 tons, as compared with 3,843,345 tons in 1897 and 3,368,349 tons in 1896, an increase of 35 per cent. over 1897, although the number of machines in use in-

creased only 10 per cent., from 224 to 245. Compared with the total product, Ohio's percentage of machine-mined product is larger than that of Pennsylvania, being 35.86 in 1898 and 31.51 in 1897.

Illinois, which is the second State in the Union in point of coal-production, shows a decrease in the machine-product for 1898 as compared with either 1897 or 1896, although the number of machines in use, and the number of firms using machines, also show a substantial increase. The decrease in the machine-mined product was due entirely to the labor-troubles which demoralized the coal-mining industry in some of the important fields of Illinois during last year. Strikes occurred in the sections of the State where machine-mining had its greatest development; and of the 1,500,000 tons' decrease in the production of coal in Illinois during 1898, one-third was the decrease in the production of machine-mined coal. In West Virginia, which now outranks Ohio in coal-production, the introduction of machines has been comparatively slow, on account of the cheapness of hand-labor; but this State shows a machine-product in 1898 of 1,323,929 tons, which is practically double that of 1897 and a little over three times that of 1896. Alabama, the fifth State in coal-producing importance, has also cheap labor. Some of the larger mines are operated by convicts hired from the State, and the machine-mined product is small, amounting to only 4.5 per cent. of the total output in 1898, and 5 per cent. in 1897. Indiana, which with Illinois, Ohio and Pennsylvania form what are known as the competitive fields, had 233 machines in use in 1898 as compared with 174 in 1897, and the machine-product increased from 1,023,361 tons in 1897 to 1,414,342 tons in 1898.

Out of the nineteen States and Territories (excluding Alaska) which produced coal by the use of machines in both 1897 and 1898, there were five the machine-mined product of which in 1898 was less than in 1897. In Colorado the machine-mined product decreased about one-third, by reason of strikes and consequent loss of time in the lignite-mines of Boulder county, where a number of machines are in use. The cause of the decrease in Illinois has already been explained. The decrease in the machine-mined product of Montana is a portion of the decrease of 168,000 tons in the total product of that State. No expla-

nation is given for the decrease in the machine-mined product of Missouri and Virginia.

Bituminous Coal Mined by Machines in the United States in 1898.

State.	Number of Firms Using Machines.	Number of Machines in Use.	Number of Tons Mined by Machines.	Total Tonnage.	Percentage of Total Product Mined by Machines
Alabama	2	37	298,170	6,535,283	4.56
Alaska*					
Arkansas	1	21	152,192	1,205,479	12.63
Colorado	8	43	225,646	4,053,112	5.57
Illinois	40	392	3,415,635	18,599,299	18.36
Indiana	13	233	1,414,342	4,922,453	28.73
Indian Territory	4	75	274,370	1,381,466	19.86
Iowa	9	56	218,852	4,618,842	4.74
Kansas	1	2	11,722	3,406,555	0.34
Kentucky	16	158	1,366,676	3,887,917	35.15
Michigan	1	7	1,456	315,722	0.46
Missouri	1	4	52,864	2,686,917	1.97
Montana	4	62	681,613	1,479,803	46.06
New Mexico	2	29	163,849	992,288	16.51
North Dakota	3	7	65,030	83,895	77.51
Ohio	52	245	5,191,375	14,476,531	35.86
Pennsylvania	99	1,085	16,512,480	65,155,844	25.34
Tennessee	4	19	152,002	3,022,896	5.03
Texas	1	5	15,340	686,734	2.23
Utah					
Virginia	1	8	244,170	1,815,274	13.45
Washington					
West Virginia	22	86	1,323,929	16,700,999	7.93
Wyoming	3	48	631,431	2,863,812	22.05
Total	287	2,622	32,413,144	158,891,121	20.40

Note on Plate-Amalgamation.

BY ALLAN J. CLARK, LEAD, SOUTH DAKOTA.

(California Meeting, September, 1899.)

In his paper on "The Accumulation of Amalgam on Copper Plates,"† Mr. R. T. Bayliss records the fact that at the Drummond mill, at Marysville, Montana, a series of tests proved that silver, instead of showing a strong affinity with the amalgamated surface of the copper plates, gave evidence of a persistent tendency to escape amalgamation; the fineness of the amalgam, as measured in gold, being highest nearest to the battery, and giving place to a constantly-increasing proportion

* Not reported in 1898.

† *Trans.*, xxvi., 33.

of silver as the amalgam was deposited upon the copper plates at greater distances from the battery discharge.

On reading this paper during the summer of 1897, it occurred to my mind that the extremely large plate-surface presented in the mills of the Homestake Company would offer almost ideal conditions for the observation of this phenomenon. With this object in view, the experiments recorded in Table I. were conducted.

In view of Prof. Hofman's exhaustive description of the Homestake milling practice,* only a brief summary of the conditions of the test will be necessary.

All the samples were taken from the Golden Star mill—a full series on the same day. In several cases more than one sample was taken, but the results always coincided very closely with those given in the table.

The pulp from the battery was in contact with the following amalgamating-surfaces:

1. The inside plate of copper.
2. The "first row" plate of copper, 12 feet by 4 feet 6 inches in size.
3. The "second row" plate of copper, plated with 1 ounce of silver to the square foot, and 12 feet by 4 feet 6 inches in size.
4. The "third row" plate of copper, same as the second row.
5. The "fourth row" plate of copper, same as the second row.

At the period of the experiments the plates of the last three rows had seen an average service of about one year; those of the second row having been in place some time before those of the third row, which were, in turn, older than those of the fourth row.

The results of these experiments apparently confirmed Mr. Bayliss's experience in every detail. At least, that was the writer's conclusion; and he thought no more of the matter until, during the first months of 1899, another series of analyses, undertaken with another object in view, brought the subject again to mind.

During the interval—to be more exact, in July and August,

* *Trans.*, xvii., 498.

1898—the plates of the second, third and fourth rows were taken up, thoroughly cleaned, and replated at the works with two ounces of silver to the square foot. They had, therefore, been in use about six months at the period of the new tests, and were in perfect condition. These assays were not made from small samples, but from the entire product of the plates of four batteries during a period of three months, assays being made after each semi-monthly retorting during this period.

The results are recorded in Table II. As will be noticed, these figures are an absolute contradiction of those previously obtained.

It is with the hope of eliciting discussion from the members of the Institute, and perhaps learning of similar experiences, that this note is written.

To the writer, it would appear that the following is a probable explanation, though he must admit that it is pure theorizing on his part, and that he can bring forward no authorities to support his view.

In the first tests the silvered plates, carrying but a light deposit of silver when put down, and having been in service for a considerable time, must have lost a considerable amount of their silver, and must have been approaching the condition of the plain copper plates; while, in the second series, the heavier silver-deposit and the shorter service make it certain that the silvered surface was intact. It would seem, therefore, that the explanation must rest upon the amalgamated surface—copper in the one case, and silver in the other; and that the tendency of the silver in the pulp to resist amalgamation decreases, if it does not entirely disappear, when thoroughly silver-plated surfaces are used in amalgamating.

TABLE I.—*Tests Made in* 1897.

Sample from	Fineness. Gold.	Fineness. Silver.	Ratio of Gold to Silver.	Remarks.
Inside plate, ...	818	168	4.87 to 1	
Copper plate, 1st row, ...	812	175	4.65	
Silvered plate, 2d "	654	331	1.97	
" " 3d "	618	376	1.64	
" " 4th "	513	465	1.10	
Copper plate, head of 1st row, .	809	180	4.49	These are somewhat below the average values for 1st row amalgam.
" " foot " " .	784	185	4.14	

Difference in average gold-fineness between 2d and 4th rows, 141.

TABLE II.—*Tests Made in* 1899.

Sample from	Highest Gold-Fineness	Highest Silver.	Lowest Gold.	Lowest Silver.	Average Gold.	Average Silver.	Average Ratio.
Silvered plate, 2d row,	573	429	558	408	564	421	1.34
" " 3d "	580	433	555	410	569	422	1.35
" " 4th "	566	452	542	425	558	433	1.29

Difference in average gold-fineness between 2d and 4th rows, 6.

Rock-Salt in Louisiana.

BY A. F. LUCAS, LAFAYETTE, LA.

(California Meeting, September, 1899.)

THE rock-salt deposit of Petite Anse, in Louisiana, has been known for many years. A description of it, with an account of the method pursued in its exploitation, was contributed in 1888 to the *Transactions* of the Institute* by Mr. Richard A. Pomeroy. But this locality does not by any means comprise the whole of the resources of the State in rock-salt. A few months ago the writer published a general account† of all the Louisiana localities now known, together with particulars concerning their technical and commercial development. In view of the fact that active enterprises in this line have increased in number, and promise to constitute an important, if not controlling, factor in the supply of salt for the immense demand of the United States (including, as it does, the consumption of this mineral as a raw material in chemical manufactures), the present paper has been prepared. While it necessarily contains much of the substance of the article above mentioned, it is accompanied with illustrations and details not heretofore published. Moreover, the former article is out of print, the publishers having no copies left of the number of their journal in which it appeared, and the writer is therefore warranted in the belief that a paper placing the essential facts on record in a form more permanently accessible to mining engineers will be acceptable to the members of the Institute.

* *Trans.*, xvii., 107.

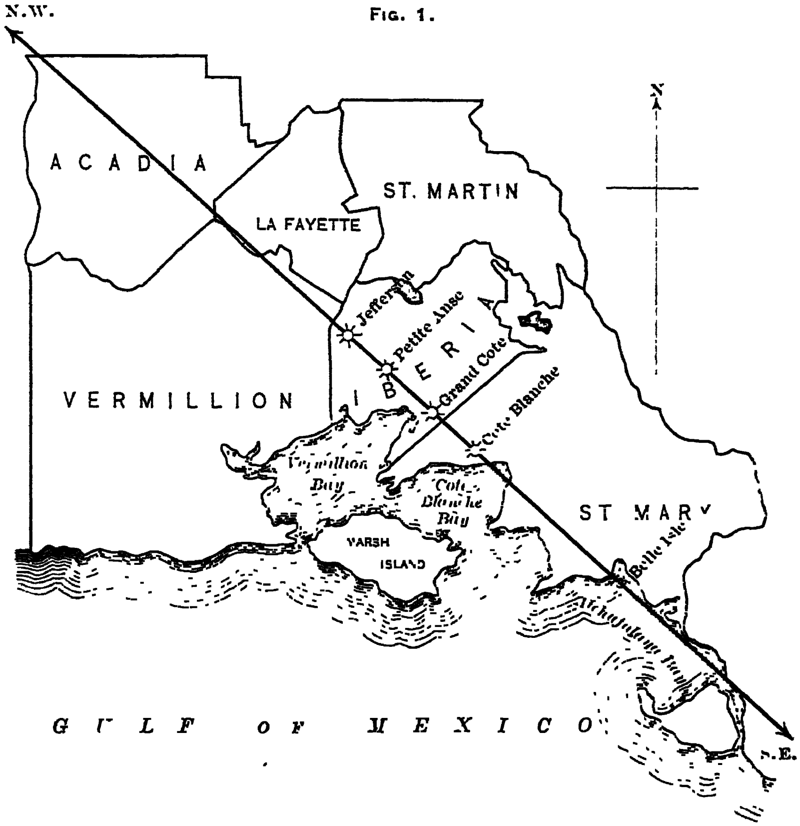
† *Am. Manufacturer*, Pittsburgh, Pa., December 23, 1898.

THE DEPOSITS.

Up to the present time four deposits of rock-salt have been discovered in Louisiana, occupying a series of so-called "islands," situated in a N.W. and S.E. line on the gulf coast. The map, Fig. 1, shows their positions. Beginning on the N.W., they are:

1. Jefferson island, about 300 acres in extent (though more than 8000 acres of surrounding land belong to the property).

FIG. 1.



MAP OF PART OF LOUISIANA, SHOWING LOCATION OF ROCK-SALT DEPOSITS.

2. Petite Anse (1600 acres), 6 miles in an air-line S.E. of Jefferson.

3. Grand Côte (about 3000 acres), 7 miles S.E. from Petite Anse.

4. Côte Blanche (about 2000 acres), 10 miles S.E. from Grand Côte. (No explorations have been made on this island.)

5. Belle Isle (800 acres, with highland- and marsh-pastures making an aggregate area of about 3000 acres), 50 miles from

Côte Blanche. Belle Isle is bounded by Atchafalaya bay and two large tributaries thereof, known as Wax and Doctor bayous. It is really the only one of the list which can be seriously considered as an island. The others are divided from the marshy mainland by bayous only a few feet wide, and spanned by bridges of insignificant length, access to which is given by low embankments through the marsh. Yet the term "islands" is justified for all of them by the circumstance that they rise from 80 to 250 feet above the surrounding marshes, which are nearly at tide-level.

HISTORY.

These elevations form the most conspicuous landmarks for hundreds of miles along the coast of the Gulf of Mexico, and played an important part in the operations of the buccaneers of the latter part of the eighteenth century, and of the transition period extending into the present century, during which Louisiana passed from Spain to France and from France to the United States. The favorable location of Belle Isle in the waters of Atchafalaya bay made it the rendezvous of the famous pirate, Lafitte, and his companions, early in this century. Numerous legends are still afloat concerning treasure buried by these adventurers on some part of the island; and the existence in the neighboring bayous of sundry old sunken wrecks, popularly believed to be relics of the buccaneer fleet, has confirmed the traditional conviction of the old Spanish and French creole inhabitants of the region. Occasionally midnight expeditions are still made by the possessors of ancient yellow parchment maps, treasured as family heirlooms, and priceless, if they were only precise! The adventurers dig pits and trenches, generally near some giant live-oak; but there is no authentic record of their success, though there are current reports of some mythical Monsieur Leblanc or Lenoir who suddenly became rich, and, of course, owed his wealth to the discovery of the secret hoard of Lafitte.

The real hidden treasure was entirely overlooked until, in 1862, rock-salt was accidentally discovered within 20 feet of the surface, at Petite Anse, by a negro, digging a well. The Confederate government took possession of the deposit, and worked it until the Union forces, attacking by land and sea, destroyed the works. They were not rebuilt until 1879, when

a company of Charleston and St. Louis capitalists leased the property. This company made a costly and fatal mistake in spending much money for dredging bayous, cutting canals, and establishing a fleet of schooners and barges, for a system of transportation which involved three handlings of the product, as well as serious interruptions, due to the grounding of barges on the mud-flats, and the consequent obstruction of the bayous, before the loading of the schooners in the bay. The company was finally merged into the New Iberia Salt Co., having its headquarters in New York, which induced the Morgan's Louisiana and Texas railroad (now part of the Atlantic system of the Southern Pacific) to build a branch, ten miles long, from New Iberia, on its main line, to the salt-mine—an arrangement which has given satisfactory transportation ever since. Concerning the methods of exploration and exploitation pursued at the Petite Anse (or Avery) mine, something will be said under a separate heading below.

This mine had no rival in Louisiana from 1879 until 1896, when salt was discovered by Mr. Joseph Jefferson, the veteran American actor, upon the nearest island, some 7 miles to the N.W., which he had owned for many years, and which, formerly known as Miller's island, had been named by him Orange island, on account of the extensive orange-groves which he had planted there. It is now called Jefferson island; and the nearest railroad station, about 2 miles away, is Bob Acres. Mr. Jefferson, impressed with the belief that mineral waters of some kind existed under the hill upon which his house stood, made repeated attempts, during his periodical winter visits, to bore artesian wells. At last, the writer took charge of the boring, which resulted, in 1896, in the discovery, at the depth of 290 feet, of a magnificent bed of rock-salt. This discovery was followed by systematic explorations, determining a zone, within which rock-salt was encountered at from 90 to 350 feet from the surface. In 1897 the writer found rock-salt by boring on Belle Isle and Grand Côte.

Geological Features.

The geological formation of this series of islands is undoubtedly Quaternary, while the salt-deposits belong to the Tertiary period, and are supposed to rest on the Cretaceous. With the

exception of 2 feet or more of rich loam, constituting the subsoil, all the islands are covered with drift-sand of the Lafayette and Port Hudson formations.*

During the explorations on Belle Isle the substratum of the S.E. part of the island, down to the rock-salt, was found to be heavily impregnated with petroleum, and several calcareous strata containing considerable brimstone were encountered, suggesting that more thorough explorations may develop a sulphur-deposit like the great Calcasieu bed—with this important difference, that the Calcasieu sulphur-deposit is overlain by hundreds of feet of impassable quicksand, while the ground at Belle Isle is practically hard and dry.

In boring to the salt, the auger passes occasionally through mud-lumps, or "lob-lolly," and, at times, through thin strata of lignite. Just before reaching the salt, a crust of conglomerate, or "hard-pan," is encountered, which is sometimes so hard as to offer considerable resistance to the tool.

In some instances gravel was found, which resisted the descent of the stand-pipe, and compelled the operator to reduce the diameter of the bore-hole.

Methods and Results of Exploration and Exploitation.

Contrary to logical order, the exploitation of Louisiana rock-salt preceded systematic exploration. It was assumed at Petite Anse that the deposit was a horizontal bed; and the shaft sunk by the first operators (indeed, the only shaft ever successfully sunk at Petite Anse) was unfortunately located in a basin surrounded by hills, and receiving the drainage of a considerable area. This shaft was carried 60 feet into the salt, and stoping was then done to the height of 35 or 40 feet, leaving too thin a mass of the salt for a roof. It was soon found that cracks existed in this roof, through which the percolation of surface-water, cutting the salt like a knife, and also carrying with it large amounts of sand, caused serious expense and trouble. In fact, besides these items of labor and cost, immense cavings, from which the mine never recovered, were due to this cause.

During the writer's administration of this mine, numerous attempts were made to prevent or retard this caving—such as the construction of mattresses of timber and brush, leaves, bag-

* Hilgard: *Reconnoissance of S.E. Louisiana.*

ging, etc., which proved only temporarily effective. It became necessary at last to check the destructive caving by building a series of cribbings and shelves, and filling up the abutments with sacks full of sand. When a spring or water-course was definitely apparent, it was led out of harm's way in troughs. At the same time, rank grasses were planted on the surface, in the hope that their roots would hold the soil together. These devices can scarcely be said to have remedied completely the original errors of exploitation; and at the present time the work is carried on in a desultory way only. It is, however, reported that a New York company will sink a new shaft, and erect a new plant, for the proper development of this deposit.

Before describing the methods of working at the other Louisiana mines, an account of the processes and results of exploration employed will be in order.

Methods of Exploration.—The explorations on Jefferson island were conducted by the so-called "jetting" system. A 6-inch pipe was forced down with a pile-driver as far as it would go; then the ground below, in the axis of the pipe, was pierced with a jet from a 2-inch pipe; then the lining was "telescoped" with a 4-inch pipe, driven through and beyond the 6-inch pipe; and this process was repeated, reducing the lining-pipe to 2.5-inch diameter, and so on, until the salt was reached. This method proved slow and expensive, and involved special uncertainties, by reason of the impossibility of knowing exactly at what depth the salt would be encountered. In some instances, for example, the writer found the surface of the salt-bed to dip nearly 150 feet in a distance of 600 feet from a point where it had been already reached by boring. In fact, this salt-formation does not lie in undisturbed stratification, like those of New York and Kansas, but seems to have been folded and contorted while still in plastic condition—a history, of which the evidences still remain in the marks on the walls of the excavated chambers, comparable to the "graining" of quartered oak, walnut or mahogany.

In exploring Belle Isle and Grand Côte, the deposit was sounded by a more effective and economical method of sinking through drift-sand. A 4- or 6-inch pipe, with a simple cutter (made by "ragging" the edge of a sleeve) at the lower end, is driven downward with a constantly revolving motion, while

water is forced through it by means of a "circulating-pump," connected by hose with a "wet swivel" at the top of the pipe. When it is necessary to add a new length of pipe, the length already in place is left to rest on the "slip-tongues" against the sleeves, and (care being taken to make sure that the connections involved are in proper condition and clean) the swivel is quickly unscrewed from the standing pipe, and a new length, already provided at its top with a swivel and hose-connection to the pump, is screwed in; after which, the pump, which has been slacked for a moment, resumes its normal work. It is highly important that this operation should be rapidly performed, as a stoppage or prolonged diminution of the water-pressure in the hole may permit the caving of sand and muck, choking the circulation. Green hands get drenched in making the connections, until they learn by experience the importance of celerity. In case of the choking of the circulation, it may be re-established by alternately raising and lowering the whole line of pipe. If this fails, the pipe is "jacked" out, in order to save it. Instances have occurred, however, in the writer's experience, in which the sand held the line of pipe so tightly that it parted at its weakest point, rather than come out.

With proper training of workmen, such difficulties may be measurably avoided, and the risk of their occurrence is not great enough to offset the advantages of the system, by means of which the writer has been able to go through as much as 400 feet of drift, and reach the salt-bed, in less than eight hours!

When the salt-rock has been reached, the original stand-pipe is "telescoped" with a 3-inch casing, a tight joint being made by "chopping" a foot or two into the rock; and the hole is then ready for the diamond-drill, which is used to test the depth and character of the salt-deposit. This system (unless gravel or other impediments be encountered) is far superior in economy of pipe, labor and time to the "jetting" system first described.

The diamond-drill used in these explorations was of style B, furnished by the Sullivan Machinery Co., Chicago, Ill., and, though roughly handled and shifted from place to place for three years, required practically no repairs during that period.

This is, perhaps, the more remarkable, since the water used in the drilling was saturated brine, the use of which, in this work, is necessary to prevent the diminution, by solution, of the 1$\frac{13}{16}$-inch core obtained by drilling, and also to prevent the enlargement, by the same cause, of the 2½-inch hole made by the bit, and the consequent "flapping" of the rod at considerable depths.

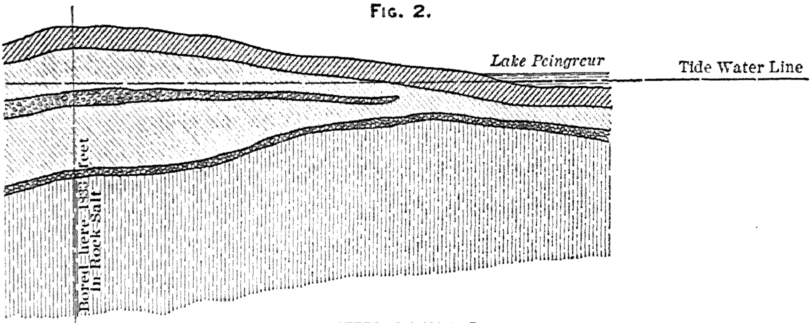
The purpose of exploration is to determine for each deposit, first, the position of the point nearest to the surface; secondly, the area to which the operations of mining will be limited; thirdly, the most advantageous location for a shaft, and the nature of the ground through which it would have to pass; and fourthly (by means of cores from the diamond-drill), the quality of the salt-rock in that locality.

Results of Exploration.—Figs. 2, 3, 4 and 5 show the sections determined at Jefferson, Petite Anse, Grand Côte and Belle Isle, respectively, by the exploration of those properties. The general result of these investigations has been to demonstrate the existence of relatively small and isolated beds of the best rock-salt thus far discovered on this continent, all of which are accessible by shafts for mining. The term "small" applies to their horizontal area only. What they lack in this respect, as compared with other known deposits, is overwhelmingly made up in their depth. Repeated attempts have been made, without success, to reach this lower limit by deep borings. In one instance, a hole was bored by the author, on Jefferson island, to the depth of 2100 feet, without passing through the salt, and without finding in it any intercalated strata of foreign material to mar its purity. This is the more remarkable, in view of the fact that all other rock-salt beds known in the United States lie 1000 feet or more below the surface, and show layers of salt from 2 to 18 feet thick, alternating with or bounded by limestone, sandstone, gypsum, shale, etc., which make the immediate product of mining more or less impure.

The advantages of the Louisiana deposits consist, therefore, in their nearness to the surface, their exceptional purity,* and the practicability of mining them as simple underground quarries, without fear of the incidental extraction of foreign materials, to the injury of the product.

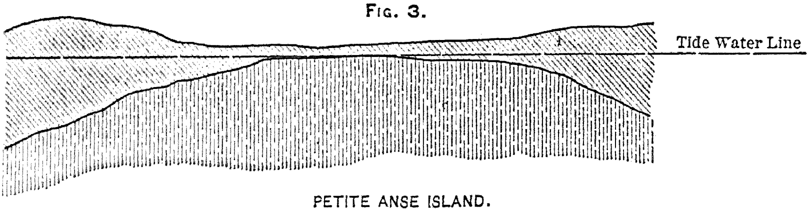
* Numerous analyses, taken at random, show an average of from 98 to 99 per cent. of sodium chloride.

Fig. 2.



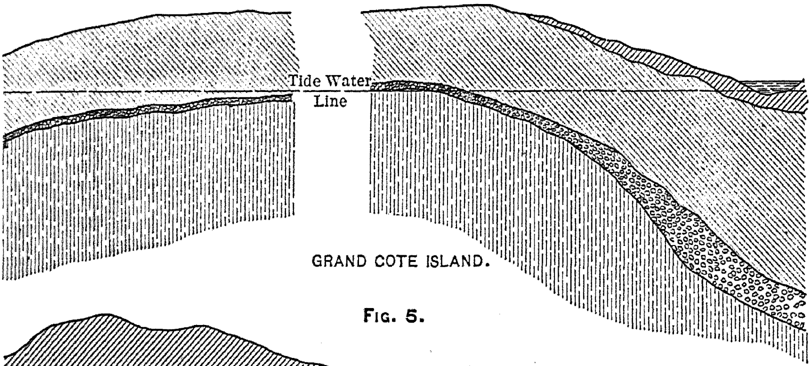
JEFFERSON ISLAND.

Fig. 3.



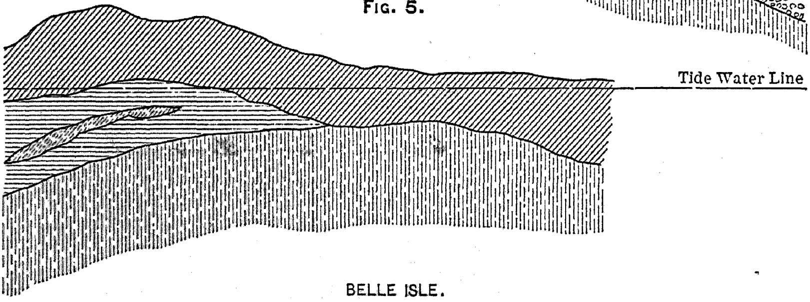
PETITE ANSE ISLAND.

Fig. 4.



GRAND COTE ISLAND.

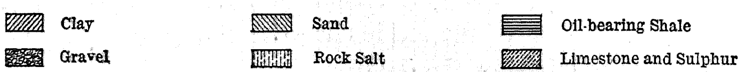
Fig. 5.



BELLE ISLE.

Sectional Views of Louisiana Rock Salt Deposits.

Scale, 1 inch = 800 feet



These advantages are to some extent counterbalanced by the presence of the overlying drift-sand, which necessitates expensive water-tight shafts to reach the deposit, and renders expedient, for the security of the mine-workings, to begin by sinking at least 200 or 300 feet in the deposit, in order to obtain, in the absence of other solid rock-roof, a sufficient thickness of the salt itself.

Another present disadvantage may be considered to lie in the circumstance that the Louisiana salt-mining industry is dependent upon a single railroad-line for transportation to its principal market in the Northwest.

The depth at which salt is reached varies in the different deposits. At Petite Anse it seems to be smaller than elsewhere. On Jefferson island it varies from 90 to 345 feet; and similar variations are shown at Grand Côte and Belle Isle.

It can scarcely be doubted that, at an unknown depth, this group of deposits is connected with a continuous stratum of salt, which may possibly extend as far as Saline, in the northwestern part of Texas, where brine is pumped, and some evaporating plants are located.

Present Methods of Working.—The mines are operated by the chamber-and-pillar system, and the salt is excavated by undercutting. When the shaft has reached a depth of, say, 250 feet or more below the apex of the deposit, stations are opened, and an undercut 7 feet high, with a face of 75 feet, is commenced. When this has advanced, say, 200 or 300 feet, the roof is attacked and blasted down to the height of about 20 feet. After the removal of the salt thus won, there remains a chamber, say, 75 feet wide by 200 feet long and 20 feet high, in which the roof is again broken down to the final height of 70 feet in the center and 60 feet at the pillars on either side, leaving a natural arch of rock-salt, which has proved capable of resisting any overlying weight, as well as preventing leakage of surface-waters.

This final excavation is performed with the aid of tripods, made of short ladders, upon which a temporary scaffold is erected for men and machines. A battery of holes, 10 feet deep, is drilled near the brow of the chamber and along its whole face, and charged with low explosives. The ladders and machines are then removed, and the salt is blasted down.

On the pile of this material, new scaffolding is erected: and the operation of drilling and blasting is repeated, until the desired height of roof is reached. Loose blocks or chips are carefully removed from the final roof, so as to leave a safely solid mass; and the chamber is then abandoned. Every such chamber, 200 feet long by 75 feet wide and 65 feet in average height, yields about 50,000 tons of salt, mined without the use of a single stick of timbering.

Pillars 60 feet square are left between chambers. Whenever a given level shall have been worked out on this plan, it will only be necessary to sink the shaft another hundred feet and repeat the operations described.

It need scarcely be said that these great vaulted chambers, with their piers and arches of pure crystalline salt, present, especially when scintillating under the strong illumination of a calcium or electric light, a most impressive appearance, not paralleled by underground views in ordinary mines. They might easily be fancied to have been the subterranean residences of the mastodons, the bones of which are so frequently found in the overlying drift.

The first undercut of salt is well shattered by blasting, and goes to the mill to be ground fine. The first and second roof-blasting furnish pieces of solid rock, which is set aside under sheds, to be aerated or weathered before being shipped for "cattle"-purposes. All finer stuff is "grist;" and as, by reason of the uniform purity of the salt, no sorting or purification is required, every pound of salt mined is a pound sold.

In a properly conducted mine, two chambers should be always worked simultaneously, since one undercut alone would not supply the coarser grades. While one chamber is being undercut, the other, with its roof partly down, equalizes the proportions of the different sizes required for steady operations.

It is not necessary to describe the crushing and sizing of the product. It is all equally pure, and is subjected only to such operations as will recommend it to the various branches of trade. The coarsest crushed salt is used principally by beef- and pork-packers; the second and third sizes are largely employed in salting hides, in refrigerating, etc.; and there are four grades of still higher fineness, produced by grinding with

emery-wheels, screening and blowing, which have their several uses—the finest being table-salt.

Commercial Enterprises, Present and Prospective.

Two companies are now engaged in erecting plants for the mining and marketing of salt.

One of these is the Gulf Co., operating on Belle Isle, and composed of capitalists in Chicago and the Northwest. Its plant is well advanced, and, having been executed with the aid of ample means, embodies, both above and underground, the best arrangements and devices that can be adopted by a skillful and far-sighted management for the production and handling of a large tonnage. A spacious canal has been cut, through which large steamboats can come directly to the great warehouse, so that steamers and barges can be mechanically loaded. As the main shaft is only 500 feet from the warehouse, the facilities for cheaply handling a large output are evidently complete. The shaft, which has three compartments, is now 400 feet deep, or 305 feet in solid and pure rock-salt; and the hoisting-machinery is of adequately large capacity. The mill is nearly finished, as is likewise a large evaporating-plant, to be used in enabling the company (aided by its proximity to New Orleans) to compete with imported evaporated salt. The plant comprises also a barrel-factory, saw-mill, large electric plant, barges, and a number of steamboats, one of which is larger than any on the Mississippi.

The other company referred to is erecting a large new plant on Petite Anse. The Avery Salt Mining Co., formed in July, 1898, by the owners of the island, upon the surrender of the lease held by the last operators, Messrs. Myles & Co., has been absorbed by the Retsof Co., of New York, which is now operating this interesting property, retaining the name of the Avery Co.

Messrs. Myles & Co., after surrendering, in July, 1898, their lease on Petite Anse, organized the Myles Salt Co., to operate upon Grand Côte island, where they had already begun in April, 1898, the sinking of a shaft. This operation has been hindered by the occurrence of quicksand just above the salt, which has thus far prevented the establishment of the tight "seal" between the shaft and the salt-rock, required to prevent the entrance of surface-waters. In order to complete a commercial enterprise, this company will have to build about 5 miles of

railroad across the marshes, to Louisa, the present terminal of the Cypremort branch of the Southern Pacific system.

Jefferson island is not under active development; Mr. Jefferson has decided to leave the property, for the present, as it is.

Of all these deposits, Belle Isle is by far the best located geographically, being adjacent to deep-water transportation; and undoubtedly it will command not only the Gulf coast trade, but may become a serious competitor on the Atlantic coast as well. Belle Isle is located 30 miles from Morgan City, on the Southern Pacific railway, and about 50 miles from Indian Village, on the Texas Pacific railway, two strong competing lines. Besides, the Plaquemine locks are being hastened to completion by the government, and a short-cut inlet will soon be made into the Mississippi river, opposite Baton Rouge. From this point barges can be towed to New Orleans, Memphis, St. Louis, Cincinnati, etc. The company proposes to transfer the bulk of its product by means of floating elevators, as practiced in New York, Buffalo, etc. By such means, it will not only get the benefit of water transportation, but will be able to make its own transfer on the cars direct to any point in the North or West.

The Lee Long-Wall Mining-Machine.

BY H. FOSTER BAIN, DES MOINES, IOWA.

(California Meeting, September, 1899.)

THE recent admirable paper on the general subject of coal-cutting machines presented to the Institute by Mr. E. W. Parker* leaves but little to be desired so far as the well-proven and widely-used machines are concerned. The general character of the machines in use and the range of their adaptabilities have been very well stated. It will be noted that in all cases these machines are being used in room-and-pillar work, and indeed (though attention was not directed especially by Mr. Parker to that point) they are practically confined to that work. It is probable that neither the chain breast- nor the pick-machine is, or can be, used to any great advantage in long-wall work.

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* *Ante*, pages 405–459.

The reason is obvious. The great weight thrown on the face of the coal in all long-wall work makes it impossible to maintain there such an extent of open space as is necessary for any of the machines of the types described. The chain breast- and cutter-bar machines require in practice approximately 10 to 12 feet of distance between the face and the gob; and the pick-machines, while not usually demanding so much, still need more room than can be obtained under any but the most exceptionally favorable circumstances.

Of the two general plans for working coal, long-wall and room-and-pillar, the former is, where the conditions will allow its adoption, incomparably the more economical. It does away almost entirely with the necessity for leaving coal in the ground. In well-planned and well-executed long-wall work practically all the coal is hoisted. There are, of course, many mines where nothing but room-and-pillar work is possible; but the number of mines working on the long-wall system, and the number of coal-beds which might be so mined, are probably greater than is commonly believed. So far these long-wall mines have been shut out from the benefits, direct and incidental, of the introduction of coal-cutting machines. It is true that long-wall machines of various types have been made and used for some years, and there are such machines now on the market; but even the manufacturers of the latter are conservative in their claims, and in general the benefits derived from their use have been very slight.

The earliest long-wall machines seem to have been designed in England, and were made to imitate very closely the action of the miner as he lies on his side and swings his pick under the coal. Later, horizontal revolving disks, set with teeth, were introduced; and still more recently, a projecting arm, carrying a chain armed with teeth and similar in action to the chain breast-machine, has been tried.

All of these earlier machines were heavy, bulky, uncertain in their action, and exacting in their requirements as to track; and none of them were self-propelling. They required to be anchored ahead, and moved forward by reeling up a rope or chain attached to the machine. This at once introduced the difficulty that they could only cut in a straight line, while the very nature of long-wall work requires a jagged or circular

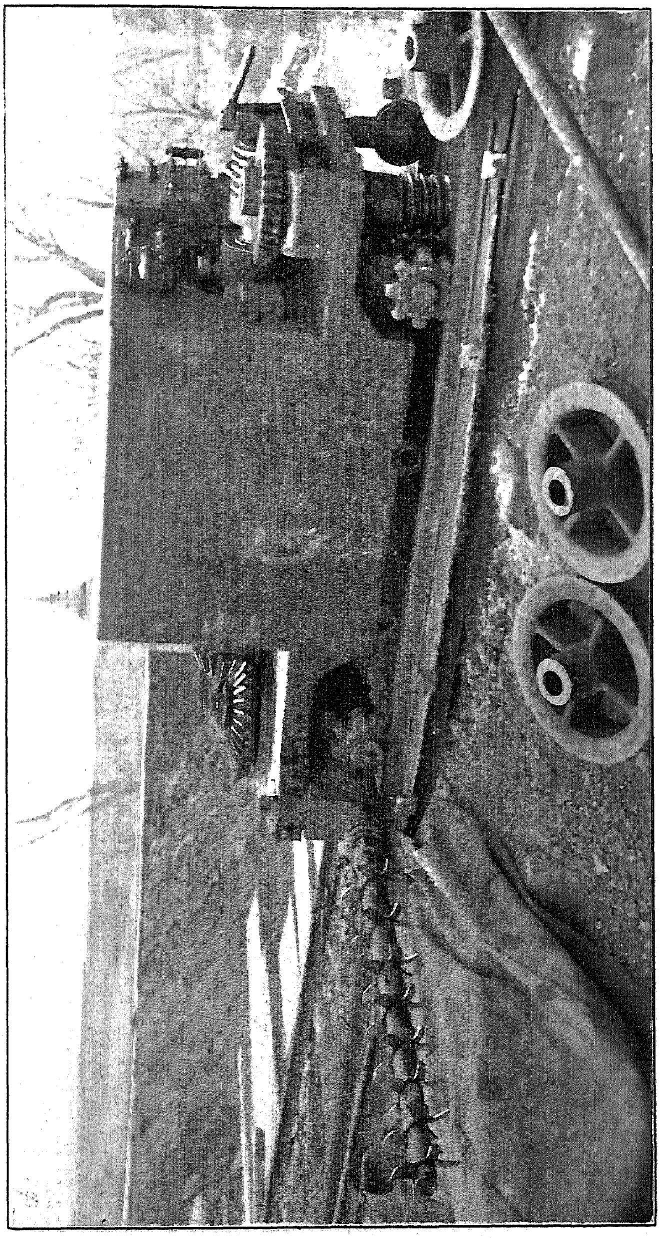
face. Some of the best of the machines now in use need to be jacked into position and held there by heavy set-screws. No great economy can be expected from their use under any but exceptionally favorable circumstances.

It has been the author's good fortune to watch the development, in its final stages at least, of a long-wall machine which is very simple in operation, remarkably successful where now used, and applicable, he thinks, to a wide range of long-wall work. This machine is not now manufactured for sale; but through the courtesy of the patentees, Messrs. David A. and Thomas E. Lee, of Centerville, Iowa, the present description of it is permitted. The development of the machine, by the way, is quite as interesting as the work which it does. It grew out of the daily needs of a small local mine, as the result of a half-dozen years of experiment and effort, and was built in a local shop, under the direction of men who had no previous training in either mechanics or electricity, but who knew very definitely what they wished to accomplish, and who paid liberally for advice when they needed it. It is interesting to note that in its embryonic history it repeated the history of the earlier machines. The first attempt at under-cutting, for example, was conducted by means of a horizontal circular saw, much like that used on one of the early English machines. This was soon discarded, and a projecting arm, around which ran a chain set with picks, was tried. This was attacking the coal as do the chain breast-machines now in use and described by Mr. Parker. It was found, however, that in travelling over the uneven floor along the face, the machine necessarily moved up and down, and this interfered with the chain, which could only cut effectively when the machine was running along a true horizontal plane. The irregular condition of the mine-floor led to the development of a spiral cutter-bar; and this has been shown to meet the conditions admirably.

The machine, which is covered by United States patents,* consists essentially of a self-propelling motor, running on a horizontal track parallel to the face and driving a projecting cutter-bar, set spirally with teeth and revolving rapidly in a horizontal plane under the coal. The different parts of the

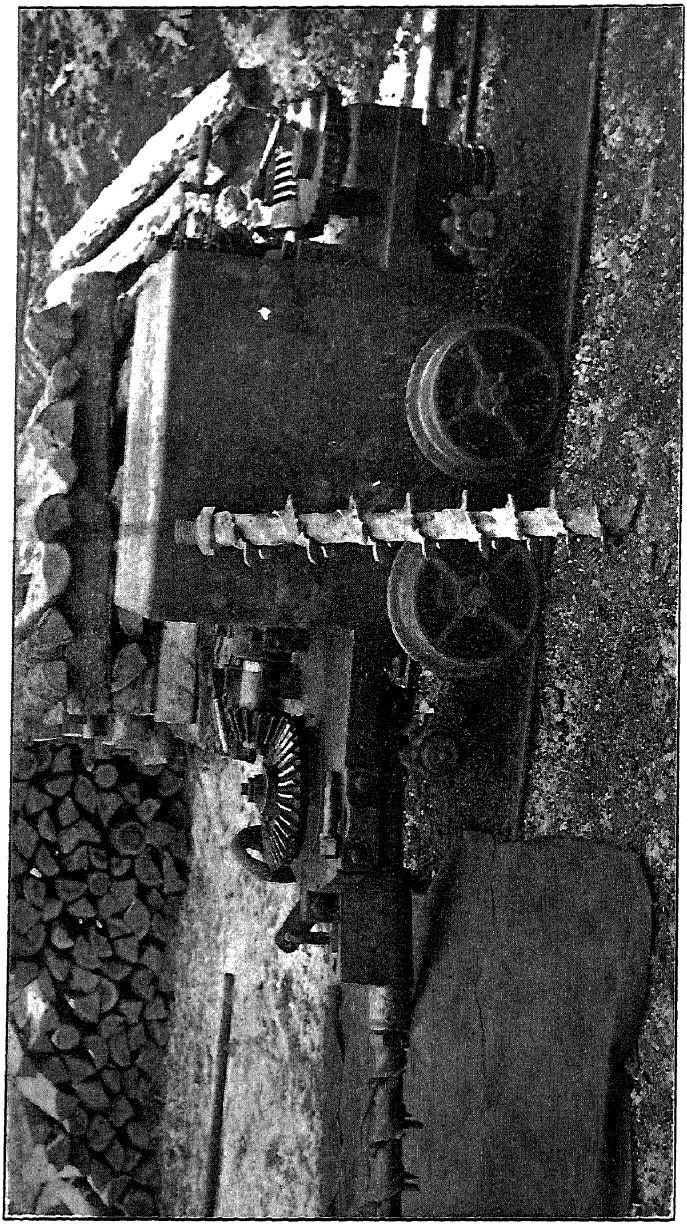
* No. 563,776, issued July 14, 1896, to James E., David A. and Thomas E. Lee, Centreville, Iowa; and No. 601,971, issued April 5, 1898, to the two latter of the same parties.

FIG. 1.



LEE LONG-WALL MINING MACHINE.

FIG. 2.



LEE LONG-WALL MINING MACHINE.

machine are shown in Figs. 1 and 2. In outside dimensions it is 24 inches wide, 52 inches long and 27 inches high. The type in use under-cuts 30 inches and weighs 3200 pounds. The motive-power is electricity, though compressed air or other power is equally applicable. The motors used are of the ordinary type used in street-car work, and are rated at 15 H. P. In ordinary work about 8 H. P., or 120 kilowatts, are used; and in hard cutting about one-fourth more is occasionally called for. The voltage employed is 220. In the first mine equipped it was found that when working 1800 feet from the engine-room there was a loss in transmission of approximately 10 per cent. This was, however, largely due to defective insulation. In the mines more recently equipped the working-losses are brought within 5 per cent. No. 0 covered wire is used for underground connections; but uncovered wires are used above-ground, to connect the central power-station with the mines. The figures given of power used include loss in transmission, and were obtained from the current-indicator in the engine-room.

The track upon which the machine runs consists of two rails, one notched and placed next to the face, and the other plain, parallel to the first, and about 18 inches away. These rails are made of common 1½-inch angle-iron. In the case of the plain rail, two bars are riveted directly together, so as to give an inverted T cross-section, with a 3-inch base. The other rail is made by using rivets ½ inch in diameter upon which shoulders are cut so as to hold the two angle-bars 1⅛ inches apart. These rivets are set at intervals of 1½ inches, and the effect is that of a flat-bottomed rack-bar. These rails are made in suitable lengths for easy handling, and two of each are required. The rack-bar is laid flat on the ground, with sprags braced against the coal, and a crow-bar brace against the roof at the rear. The outer rail is unbraced, and there are no cross-pieces connecting the rails. When the machine is running, the extra set of rails is set ahead of it; and when the machine comes upon them the sprags of the released rail are knocked loose, and the rail is shoved forward alongside the machine and relaid ahead. The operation of track-laying is carried on by the two men who operate the machine, without stopping the latter or in anyway interfering with its work. The machine propels itself by means of a suitable toothed

wheel, meshing with the rack-bar. At first glance it would seem that it would be necessary to lay the track very carefully indeed, and to brace it quite thoroughly. In fact, it is customary to use jacks in the case of other machines; but in practical work the Lee machine requires that only the slightest attention be paid to the track. Only when the bottom is wet and slippery is it necessary to use any care in placing even the few braces mentioned; and in the interval of changing the crowbar brace from the released to the engaged rail the machine seems to work quite as well as ever. The braces are more matters of precaution than otherwise. The outer or idler-wheels are swung on pivots, and hence accommodate themselves readily to horizontal irregularities in the track. Vertical irregularities are compensated by means of a device for raising or lowering each wheel separately, shown in the small handle projecting above the upper right-hand wheel in Fig. 1. By means of this device it is possible to make the machine cut up or down from the horizontal plane. This compensates for irregularities in the floor and permits cutting over or under any obstruction. It is also useful by rendering it possible to make more or less "dirt" according to the needs for packing.

It is obvious that this method of propulsion has a distinct advantage over the older plan of dragging the machine forward by winding-in an anchored wire or chain, in that horizontal irregularities of face, often essential to the success of long-wall work, are compensated. The rate of forward movement can be regulated. In the work at Mystic, the feed is 12 inches per minute; but this is sometimes exceeded. In one piece of measured work, 20 feet were cut in 18 minutes.

The essential and novel feature of the machine is the form of cutter-bar, which is, so far as known, wholly new. This bar is $2\frac{1}{4}$ inches in diameter at the machine and $1\frac{1}{2}$ at its outer end. It was first made, as shown in Fig. 2, detachable, and was screwed into a revolving shaft permanently fixed in the machine. The shaft and bar are now made in one piece, and so arranged as to be very readily slipped out and replaced when the teeth are dull. Around this bar is fastened a spiral band of steel with 42 projecting teeth, much resembling in outline the teeth of a cross-cut saw. This band is made of the best tool-steel, manufactured on special order, in slabs $2\frac{5}{8}$ by $\frac{3}{16}$ by 63 inches, by the Crescent Steel Co., of Pittsburgh. The teeth

are cut and the bars wound at local works. The teeth are set so that they do not quite cover each other; and it is estimated that the work is one-fourth cutting and three-fourths breaking. The cutter-bars are used for under-cutting about 100 linear feet, and are then reground. The latter operation takes from five to ten minutes. Each set of teeth is good for about two weeks' work, after which the three rivets which fasten the spiral to the bar proper are knocked out and a new spiral is slipped on. It is estimated that the cost of the teeth is about $\frac{3}{4}$ cent per ton of coal won.

An important feature of the cutter-bar is the spiral arrangement of the teeth, as the effect is that of a screw-conveyor in clearing out the under-cut. Another important feature is the ability to turn the bar on a vertical pivot by means of the hand-wheel, shown at the lower left-hand corner of Fig. 2. By this means the bar can be thrown to the rear, as shown in the same figure, for the purpose of changing from a dull to a sharp cutter, without disturbing the position of the machine at the face. This change requires about five minutes. By means of this device the machine is made to cut its way into the coal, so that no pick-work is necessary in starting it. This is an indispensable feature of a successful machine.

As shown in the figures, there is an arrangement for fitting truck-wheels to the machine for conveying it from point to point in the mine. All delicate machinery is carefully protected from dirt. Only those who have experimented with machines will appreciate what experimental work all these details have required. For example, the rear pinions are made of a special brass, the composition of which was only hit upon after many and repeated trials. So successful is the result, however, that a stray monkey-wrench once found its way between these wheels, to its own disaster, but without stopping the machine. The secret of the successful forward feed without heavy bracing of the track lies largely in the distribution of the weight and the use of but one propelling wheel; and this adjustment of weight came only after repeated trial.

At present twelve machines are in operation and four are building. They are all worked by the Electric Coal Co., of which the patentees are the main owners.

The coal worked is the Mystic seam, already, perhaps, sufficiently described in the reports of the Iowa Geological Sur-

vey.* It is a clean, brittle coal, worked ordinarily by pick-mining and requiring no shooting. It is of excellent quality, though thin, and furnishes about 2½ feet of good coal. A typical section would be as follows:

	Feet.	Inches.
8. Cap rock, impure limestone,	2	
7. Clod and slate,	1	
6. Coal,	1	6
5. Clay parting, soft,		2
4. Coal, clean,	1	
3. "Dutchman," sulphur and slate,	1	½
2. Coal, poor quality,		4
1. Fire-clay,	2	

The machine cuts indifferently in the fire-clay and in the coal below the "Dutchman." As this portion of the coal is of poor quality, no attempt is made to save it. In room-and-pillar work, about 2240 tons per acre are hoisted and sold. In long-wall work (but little used except in the mines of the Electric Coal Co., though coming into more general use), there is a very considerable increase in the percentage of coal won.

In ordinary every-day work the output is from 40 to 60 tons of coal, or 600 to 650 square feet of under-cut, to each machine in a working-shift of eight hours, with 2 men to each machine, and from 10 to 12 followers loading coal, building pack-walls, etc. On a record-run in March, 1897, 1362 square feet were under-cut in nine hours and fifty minutes, with a yield of 109 tons of weighed coal. The total cost for labor in under-cutting is, at present rates, 11 cents per ton. Records of repairs and breakage for twelve months showed a cost of ⅜ to ½ cent per ton. In general, as compared with hand-work in the same field, and even in the same mines, there is a saving of about 20 per cent. in the cost of machine-mined coal.

There is a large amount of coal in this field, nearly 1500 square miles, much of which is yet undeveloped. There are other beds in the region to which the machine seems applicable. In any wide application of it, changes would of course be necessary to meet local conditions; but the essential features may fairly be claimed to have been proved correct in theory and feasible in practice.

* Vol. V., pp. 363–438.

The Copper-Deposits of Vancouver Island.

BY WILLIAM M. BREWER, VICTORIA, B. C.

(California Meeting, September, 1899.)

UNTIL quite recently, in fact within the past two years, but little attention has been given to the outcrops on the west coast of Vancouver Island, and their copper-contents. During the past few months the writer has been engaged in examining and developing some of these prospects.

In many respects he has found characteristics associated with these prospects which, in his experience, are unique. In the first place, nearly all the outcroppings which overlie chalcopyrite-ore along the west coast of the island are composed of a high-grade magnetite. The magnetic qualities of some of these outcrops are so pronounced that the magnetite possesses polarity. Although the writer himself had no analyses of this magnetite made, yet from its appearance he can readily believe that analyses made for other parties, which show a yield of 62 or 63 per cent. of metallic iron, with only traces of phosphorus and silica, are correct.

At a very shallow depth, masses of chalcopyrite, yielding in some instances as high as 32.6 per cent. of copper, occur associated with the magnetite; and in one instance, which recently came under the writer's observation, a solid body of high-grade chalcopyrite, fully 4 feet in thickness, occurs within 6 feet of the surface.

Usually this solid sulphide-ore carries low values in gold. Probably an average of $2 per ton would be fairly representative. But in some instances development has determined the occurrence of narrow stringers of pyritous quartz, associated with the sulphide-ores, which yield by assay more than $20 per ton in gold.

In the districts examined by the writer, the country-rock is usually crystalline limestone, with dikes of igneous rock as intrusions. Sometimes the outcrops of magnetic iron-ore are

found in the limestone itself; but they usually occur at the contact between the limestone and igneous rock, or in fissures cutting through the igneous dikes.

Most of these dikes are apparently composed of quartz-diorite; but as no specimens have been microscopically examined, to the writer's knowledge, this classification may not be exactly correct.

The trend of the country-rock is conformable with that of the island, *i.e.*, northwesterly; but the line of strike of most of the ore-bodies is usually northerly, or northeasterly.

As lode-mining on Vancouver Island is merely in its infancy, it is impossible to present as many facts with regard to these extraordinarily rich outcrops as one would desire. In fact, 175 feet is the greatest depth which has yet been attained on any of the ore-bodies. In one instance, where this depth had been attained, the writer is informed that both the continuity and the grade of the ore were maintained. At another location, recently visited by the writer, he found that high-grade chalcopyrite occurred at a depth of about 120 feet; but as this had not been either cross-cut or drifted on, he is not prepared to give any data as to its extent.

Although the outcrops of magnetite are usually quite persistent in length, especially when they occur in fissures in the igneous dikes, yet the writer has failed to find any instance where the lodes can be traced for any very considerable distance without a break. On Bear river, at the head of Bedwell sound, which connects with Clayoquot sound, some of the outcrops can be traced easily for a distance of from 500 to 700 feet. Another instance where the outcrop can be traced for about the same distance, occurs on Anderson lake, which empties into Uchucklesit harbor, which connects with Barclay sound. Still another instance occurs near Goldstream, about 10 miles northwesterly from Victoria. This last outcrop, however, is composed of gossan instead of solid magnetite.

Usually, when the outcrops are found on the contact between the crystalline limestone and igneous rocks, they cannot be traced as readily along the line of strike as when they occur in fissures in the igneous dikes. The writer's observations have demonstrated to him that the contact-outcrops occur in masses or pockets, sometimes covering a considerable area of ground,

and often disposed in a tolerably regular line, but with no indications on the surface that there is any connection between the different pockets. It is not safe to form an unqualified opinion as to the non-maintenance of continuity along the line of strike, because the ground is often covered with such a thickness of moss or, at other times, *débris* from slides, that it would be necessary to do considerable work on the surface to prove the existence or non-existence of the outcrop. At no location known to the writer, where masses of outcrops occur along the contact, has sufficient underground work been performed to determine the continuity of the ore-bodies between the masses of outcrop.

The writer has observed several places where the outcrop of magnetic iron-ore occurs in the crystalline limestone. Such occurrences are apparently limited in extent, and do not appear to possess permanency, but rather impress one with the idea that their structure has the same pockety and irregular characteristics as belong to the limonite ore-deposits in the Southern States. The correctness of this impression can only be proved by actual mining operations, which have not been, up to the present time, sufficiently extensive on this class of outcrops to determine either the extent or permanency of the ore-bodies.

So far as the grade of the various outcrops is concerned, the writer has observed that there is but little, if any, difference between those occurring in the igneous rocks, on the contact, or in the limestone.

Besides the outcrops of chalcopyrite, bornite occurs in some localities, with heavy spar as the gangue. There is such an occurrence on Deer creek, which empties into Tofino inlet, where a fairly high-grade bornite is quite plentiful at and near the surface; but the writer is informed that as depth has been attained, the bornite has given place to chalcopyrite of good grade. A syndicate is developing this property to determine its value as a mine. According to information received, it appears that bornite is more plentiful northwest than southeast of Clayoquot sound. Except the deposit on Deer creek, the writer knows of no other discovery, where bornite has been found in any quantity, to the southeast of Sidney inlet, which is about 35 miles up the coast from Clayoquot.

The portions of the island to which the writer has given most attention are in the neighborhood of Goldstream, about 10 miles from Victoria; the Alberni canal, which connects with Barclay sound about 110 miles northwest from Victoria; and the country [illegible] to the inlets which connect with Clayoquot sound, about 160 miles northwest from Victoria. Of the coast and the interior of the island, northwest from Clayoquot sound, the writer is unable to speak, except from information.

The geology in the sections to which he has given personal attention is quite complicated. The rocks around Victoria are apparently chiefly eruptives. To the northwest, near Goldstream, there occurs a wide belt of semi-crystalline slate, slightly graphitic, in places highly metamorphosed, as, for instance, on Skirt mountain, in which the copper-deposits referred to earlier in this paper occur. This belt of slate has a general trend about N. 60° W. On the northeast of this belt occur crystalline limestone, granites, diorites and other igneous rocks, which comprise the formations, until the sandstones and conglomerates of the coal-measures are encountered, near and along the eastern coast of the island. Along the southwestern coastline a narrow belt of sandstone occurs, dipping westerly into the straits of Juan de Fuca, but broken in many places by erosion.

The belt of country in which the crystalline limestone and the igneous rocks occur forms a very interesting study in geology. But it is so complicated, and in places the faults are so numerous, though limited in extent, that a much longer period of time is requisite to make a thorough survey than the writer has been enabled to devote to such observations.

The mountains on the island vary in altitude from 1000 to about 7000 feet. They are covered with a densely heavy growth of timber and under-brush, which renders exploration in the interior extremely difficult. Consequently, prospecting operations, up to the present time, have been confined to the immediate vicinity of the shores of the inland waters and streams emptying into them. The numerous navigable waterways connecting with the Pacific ocean on the west coast of Vancouver island have furnished the means, in the past, for prospectors to explore the country near their shores, and in the

future will prove one of the most important features to aid in the development of the country, because they will furnish the cheapest possible transportation for supplies, ore, etc.

Mineral occurs in apparently three distinct zones, each of which has a northwesterly trend, while each mineral deposit has its own individual line of strike. The most southerly of these zones is the belt of semi-crystalline slate, which traverses the extreme southern portion of the island from Goldstream to near the head-waters of the San Juan river. This zone furnished, some 30-odd years ago, a considerable amount of placer-gold, which was found in the Leach and Sooke rivers and their tributaries.

Northeasterly from this belt of slate occurs the main belt of igneous rocks, which, in places, is several miles in width. In this formation are found the occurrences of magnetite and chalcopyrite.

The third zone lies northeast of the second, and apparently parallel with it. This zone embraces numerous auriferous quartz veins, sometimes quite narrow and of little if any commercial value. In it occur also the old placer-diggings on China and Granite creeks near Alberni, and on Bear river about 8 miles above its mouth. This latter stream empties into Bedwell sound, which connects with Clayoquot sound.

The writer has only very casually examined the country-rock in a portion of this zone near Alberni, where it is a hornblende-schist. Consequently he is not prepared to enter, in the present paper, upon a discussion of the geology of the district.

An imaginary line, drawn from Saanich inlet, on the southeast coast of the island, northwesterly, passing along the head of the Alberni canal, and thence to the northwest coast at Quatsino sound, would practically mark the division between the sandstones and conglomerates of the Coal-measures and the crystalline area.

On some of the numerous islands in the sounds which connect with the Pacific ocean, deposits of magnetite, with some associated copper pyrites, have been discovered; but on none of them, to the writer's knowledge, has there been any extensive development-work performed.

It may be safely said that the western portion of Vancouver

island presents to-day features of great promise, so far as copper-deposits are concerned. There are also ledges of gold-bearing quartz, some of which yield high values at and near the outcrop; but none of these have yet been thoroughly developed. Work is going on, however, in the vicinity of Alberni, as well as near the head of Bear river; and the results should determine before many months whether these occurrences of auriferous quartz possess value as mines.

The Mines and Mill of the Atacama Mineral Company, Ltd., Taltal, Chile.

BY SIDNEY H. LORAM, TALTAL, CHILE.

(California Meeting, September, 1899.)

As the work carried on by this Company, of which the writer has been in charge for the past two years, is somewhat unique, the following account of it may be of interest, and, on that account, is offered to the Institute without any attempt to claim this practice as the best.

Mines.

The mines supplying ore to the Company are situated in three groups: the Guanaco field, about 80 miles N.E. of the port of Taltal (lat. 25° S., long. 70° 30′ W. of Greenwich); the Sierra Overa, about 63 miles S.W. of Taltal; and Paranao, about 42 miles due N. of Taltal (12 miles N. of the small town of Paposo, once famous for its copper-output).

Guanaco.

This field lies in the center of an absolutely waterless mountainous desert, where not a sign of vegetation can be found for miles. The dryness is such that ivory and horn crack and open, while raw-hide must be used in place of leather, which would become worthless in a very short time. Water is brought about 21 miles by piping from the Cordillera, but only in small quantities, and costs in the Guanaco $7 (= $1.78 gold) per cubic meter. All supplies and food are sent from the port of Taltal, which in turn draws its supplies from the south of Chile, the

only connection with the outside world being by the weekly coast-steamer north and south, as the desert is, to all intents and purposes, impassable. The field is connected with Taltal by the Taltal railway, a branch of which runs into the Company's works, distant 88 miles.

The climate, although healthy, is very severe, owing to the variation of temperature between day and night, the thermometer often, for months together, ranging in 24 hours from $-3°$ to $+16°$ C. Moreover, gales of extreme violence occur during the winter (June to September). During their continuance, out-door work is sometime impossible for weeks.

The Guanaco consists of a hill, about 600 feet high, rising abruptly out of the sloping pampa (the total elevation being 9269 feet), and a much smaller hill adjoining it, the Guanacito (little Guanaco). These hills, which are completely warrened with small mines, all of which have produced gold to a greater or less extent, comprise the whole area in which the precious metal is found, within a radius of 18 leagues, with the exception of another hill, about 3 leagues distant, on the very summit of which a chimney of ore was found and worked to a depth of 90 meters with good results—but nothing was found laterally.

The origin of the Guanaco as a gold-field is somewhat obscure. There was certainly a volcanic outburst, and, in all probability, an upheaval of the plain (which consisted of porphyry, syenite and quartz, already in parts carrying gold), accompanied by the intrusion of veins of trachyte, followed by an interval of thermal water-action, accompanied by or alternating with the escape of hot vapors and considerable local heating. The whole series of processes has left a most complicated result, in which practically no regular formation remains, and which presents many curious specimens, and involves the difficulties of mining natural under such circumstances. One mine at the foot of the Guanaco exhibits the only simple lode-formation in the field.

Ore.—The general ore is an extremely compact and tough quartz, in which crystallization is microscopic, and, in some cases, absent, probably as the result of the heating, disintegration and re-cementation through which the original quartz has passed. Nearly all specimens show traces of fractures now

welded together, either with or without the intrusion of foreign matter (generally sulphate of barytes, quartz-trachyte or a distinct later deposit of clear crystals of quartz, usually less than 0.025 inch long). A specimen in the writer's possession shows four distinct classes of quartz (mostly angular), bound together in this way by trachyte and barytes crystals, and also contains two specimens of trachyte cemented with the quartz, quite distinct from the binding material, and indicating that the process has been gone through more than once.

The nearest approaches to a definite formation are what are termed *mantos*—bodies of quartz, of an oval, flattened form, of all sizes, usually pink or gray in color, and occurring without regularity. These, in general, carry the gold. Occasionally, in addition to the above-mentioned impurities, they are impregnated along the fissures with scorodite (hydrous ferric arsenate), both amorphous and crystalline, and by native sulphur in crystals, either occurring together or separately. The *mantos* which carry gold to any considerable extent are in nearly every instance less than 120 feet from the surface. The quartz found at greater depth contains only traces of gold. Several mines have struck, at 270 to 300 feet depth, copper in the form of tetrahedrite, sometimes almost pure, and in very remunerative quantities, but, as in the case of the gold, without any regular formation. Copper also occurs in small isolated patches near the surface, as silicate and sulphate, but apparently without any conformity or relation to the deeper deposits.

The total number of measured mines is about 100, of which the Company owns six, besides receiving the bulk of the product of those of other owners now actively working.

Gold.—This occurs principally under two conditions. That which has the greater value for mining is very finely divided and unequally distributed through the compact quartz, with which it is so thoroughly incorporated as to be only partially visible in specimens containing several per cent. of gold. The degree of fineness may be more clearly shown by the statement that, in the sampling-works, the final screen through which the ore has to pass contains 10,000 holes to the square inch; yet it is the rarest occurrence, even after the flattening action of crushing and grinding, to find gold that will not pass this screen. From the compact nature of the quartz, impregnation

with solutions carrying gold appears impossible; and, as every evidence tends to show that the quartz was not precipitated from thermal solutions where it is now found, the writer believes that the gold existed in the quartz prior to its present state.

The second condition under which the gold exists is that of a precipitate at a later date by thermal action, after the formation of the barytes-crystals, and both before and after the secondary deposit of quartz. It is principally confined to the fissures, and occurs as spangles on the facets of the barytes-crystals (forming specimens of rare beauty, especially when the spar is opaquely white), and also both upon and beneath the quartz crystals. Specimens showing the gold deposited upon the barytes, and the whole covered by a capping of minute clear quartz crystals, through which the gold can be distinctly seen, are by no means rare. Gold is also generally found in the pure porphyry and trachyte for a few feet from any of these formations, doubtless due to impregnation, and diminishing rapidly in value as the distance increases.

Specimens of kaolin, on which the gold has been deposited along the cleavage-planes to such an extent as to appear plated when turned to reflect the light, yet so thin as to show only a trace upon assay, were common from one particular mine, the Guadaloupe, while rare specimens have been found, in which the gold appears as beads, about 0.025 inch in diameter, imbedded in scoria. In the Inesperada mine the gold is found in vugs, associated with quartz much stained by iron, and occurs as a brown powder, showing only a partial metallic luster, in patches—indicating precipitation from solution.

The average assay of the native gold may be taken at 94.4 per cent., the balance being silver. The latter metal, however, exists in much larger quantities in the ore, as bromo-chloride or sulphide.

Mining.—This is carried on in the usual national manner; the absence of a regular formation, the want of capital, and the universal employment of tributors preventing even an attempt at systematic working. The rule is to follow the pay-ore wherever it may lead, regardless of mine-roads or levels. The appearance presented by such workings is difficult to describe. It may be likened to large caverns in limestone. No

timbering is practiced; and, in many cases, where the ore has been plentiful, there are enormous chasms, in which, where the ore has been too poor to mine, great boulders have been left hanging in a way that makes a heavy fall appear inevitable. The natural consequence is that, in many cases, fairly good ore has to be left on account of the difficulty of extraction. This work is chiefly done by *apires*—men who, with raw-hide sacks slung to their shoulders, will carry on the average 140 pounds for a vertical distance of 120 feet, making 28 to 30 journeys per day, over the worst of mine-roads and Chile ladders.*

In the larger mines horse-whims are in use or hauling is done by mule and single pulley, while one or two have steam winding-engines.

As a workman, the Chiliano is emphatically good as a miner or otherwise, working contentedly when fairly treated, or definitely refusing if not. Hand-drilling is universal; and, on the average, in Guanaco quartz, to drill and fire four shots 18 inches deep is a day's work. Powder is generally used, except where the ore is unusually hard or wet, which is rare. The average pay for day-work is $3 paper (76 cents gold).

The similarity between pay-ore and barren quartz is very close; and the irregular distribution of the gold makes sorting a matter of the first importance, as well as an art requiring considerable practice. In some cases nothing but continual assaying with the washing-horn will decide. Practice with this implement, taken together with the universal fineness of the gold, has made the miners very expert in their estimates. With an ore which they know, their calculation is practically certain to within one-half *cien milesimo* ($3.50) per ton, always providing they have no personal interest in the value. Otherwise, bias gets the better of judgment.

As already observed, practically all the mining is done on tribute or contract. This applies to all work where it is practicable, being preferred by the men, who are an independent race, and like the liberty it gives them, as well as the opportunity to earn more by hard work, which in nearly every case is the result. The consequence of the tribute-system is, that when the ores are to be sold to or realized by the works, each

* Square timbers, 4 by 4 inches in size, notched, saw-fashion, upon the upper surface, and simply laid wherever the road is vertical, or too steep to climb.

tributor must have his lots of ore separately sampled, assayed and valued. As a rule, when a mine sends down its product (every month or fifteen days), one of the tributors takes charge of it, to watch the sampling, and, in general, represent the others.

The cost of mining is so variable with different mines, and under different conditions in the same mine, that it is impossible to give figures on the subject.

Sierra Overa.

This formation is entirely different from the Guanaco. As already observed, it lies about 63 miles S.W. of Taltal, at an elevation of 5600 feet, and is connected with the port by a cart-road. All supplies and water are taken from Taltal by carts, and the ore is brought down the same way. Each cart requires six mules in good condition; its load is 6000 pounds; and the round trip takes seven days. The charge for down-freight is $24 paper ($6.12 gold) per ton.

The field is on the inner side of a crescent-shaped hill of gradual slope; the country-rock is diorite; and the lodes, which are of thermal origin, consist of crystalline quartz, highly ferruginous and banded. Most of them carry traces of copper, and the deepest workings (300 feet) show occasional specks of pyrites; but, so far, the ore is perfectly free-milling. The gold is coarser than that of the Guanaco, but still fine, and distributed pretty evenly over the whole of the quartz, besides occurring in the country-rock where the latter has been favorable to impregnation from the lode. It averages from .900 to .950 in fineness. Silver-minerals occur in small quantities; in one or two instances the value of the ore in silver is about equal to its value in gold. The veins have no common strike; the dip varies between 45° and the vertical. The lodes vary in width from a few inches to 3 feet. From the surface down to about 100 feet the ore exhibits a general tendency to grow poorer, sometimes accompanied by a pinching of the lode. Below this zone, wherever the ore has held good enough to justify continued working, there has been a steady improvement. One of the most extensively worked veins has increased from 10 inches at 100 feet, with an average assay of $42.50 per ton, to 14 inches at the present depth (300 feet), with an average assay of

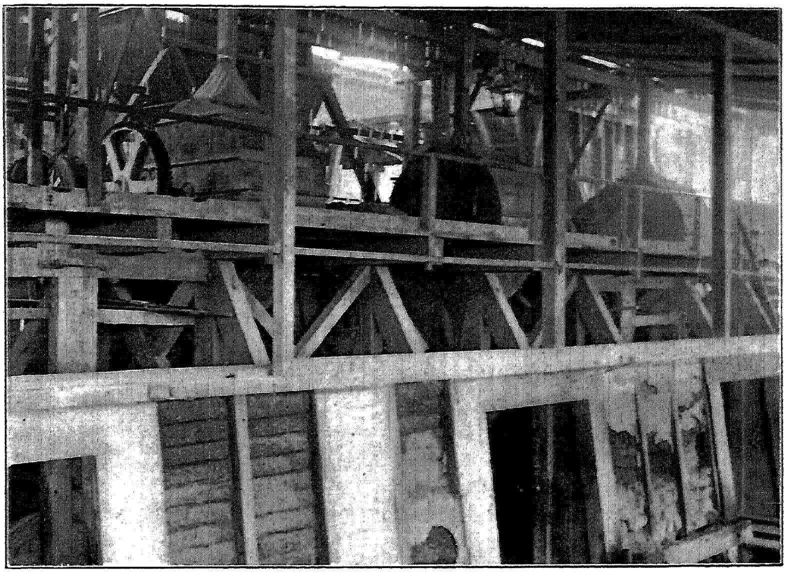
\$63.70. The method of working, where the dip permits, is to sink as many incline-shafts on the lode as the claim will allow, each about 14 by 4 feet in size, leaving 3-foot intervals, which are cut through every 12 feet, leaving just sufficient ore standing to prevent a cave. Up to date, little has been done since the discovery of the field six years ago, owing principally to the absence of water, the difficulty of access, and the impossibility of consolidation amongst the numerous small mine-owners. Nevertheless, the field promises more for the future than any other in the immediate neighborhood. Under favorable conditions, mining here may be said to cost \$28 paper (\$7.14 gold) per ton of ore placed on the floors at the surface.

Sampling and Assaying.

On arrival at the works, the ore is crushed in a Blake crusher to pass a 3-inch ring; then piled, the top trimmed flat, and one quarter taken. This is passed repeatedly through a cone, the outlet of which divides the stream into two, until the sample, which has been halved every time, weighs about 320 pounds. This is then passed through a small Blake crusher, set to crush to a half-inch ring, and then through a Clarkson rapid sampler, set to take 20 per cent. of the total, which is crushed upon a grinding-plate to pass roughly a 20-mesh sieve, and again passed through the sampler, set to take 10 per cent of the total. The residual sample is then crushed to pass a 100-mesh screen, after which, by means of a small Clarkson sampler, specially arranged, the sample is divided into four parts. Of the four packets thus made, one is assayed on account of the seller, one by the works, one sealed by both parties for reference, and one is left for possible need. Should the difference in any assays between the works and the seller amount to more than \$3.50 per ton on an ore assaying \$28.50, or to more that \$7.00 per ton above that assay, the third packet is assayed, either by a third party or by the two assayers together; their united result being final. Smaller differences than these are divided.

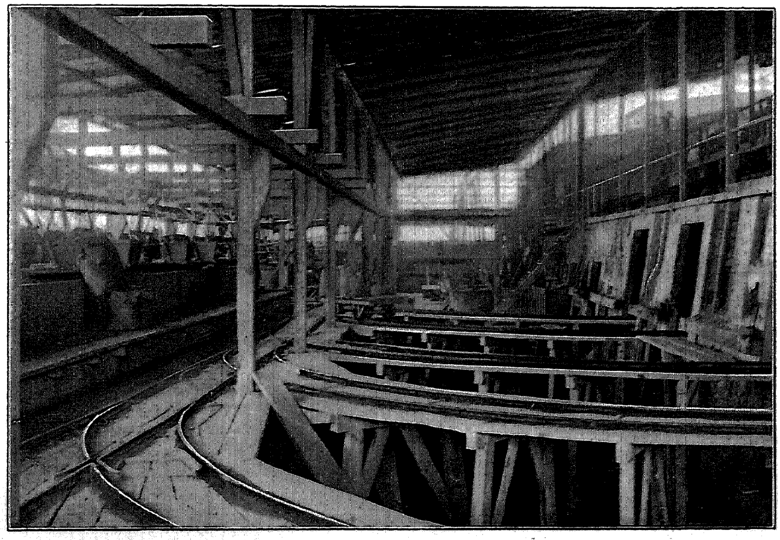
All assays are made in crucibles. Two 25-gramme lots of the ore are fluxed with, roughly, litharge 30 grammes; soda bicarbonate 45 grammes; dried borax 25 grammes, and flour 1 gramme; these proportions being varied slightly, according to the ore. The same crucibles serve for from six to ten charges.

Fig. 1.



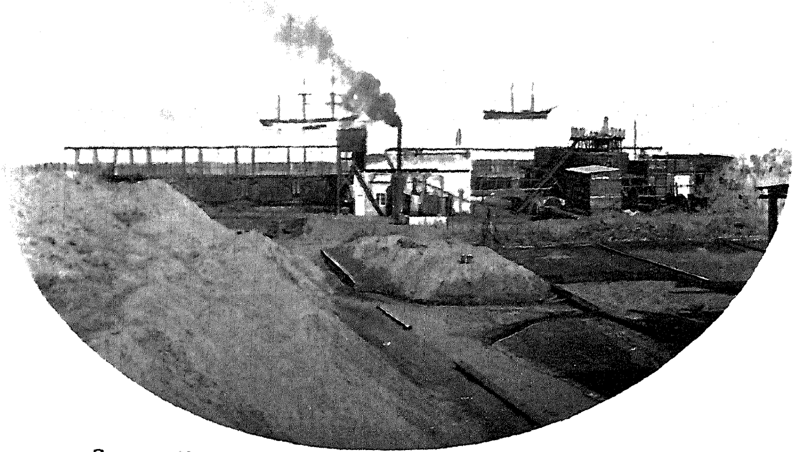
Gruson Mills

Fig. 2.



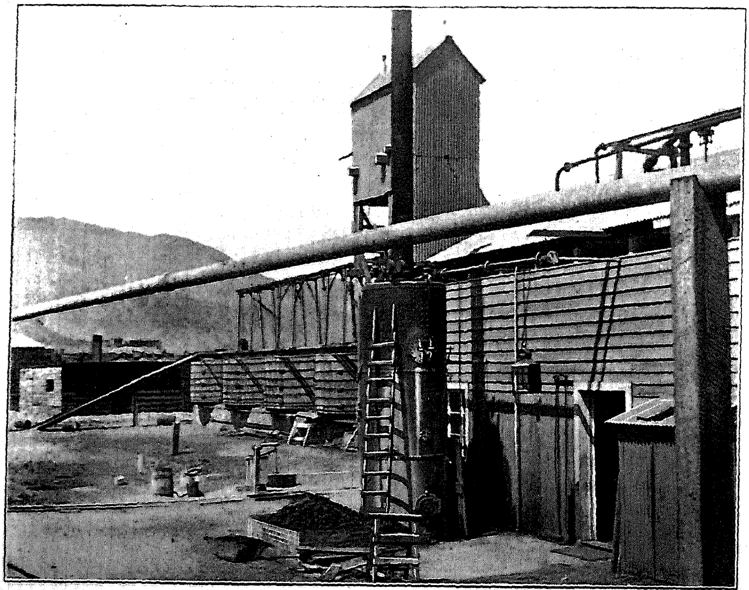
Amalgamating-Plant. Grinding-Mills on the right.

FIG. 3.



GENERAL VIEW OF CYANIDE PLANT, WITH SEA IN THE BACKGROUND.

FIG. 4.



CYANIDE PLANT

All accounts, weights and assays are upon the metric system. The assays are reported as so many hundred thousandth parts (*cien milesimos*) for gold and ten thousandth parts (*diez milesimos*) for silver. Ores are purchased upon their fine contents of the precious metal in kilos, higher prices being paid per kilo of metal contained for higher assays, since it is contained in less weight of ore. Thus, with an ore assaying two *cien milesimos* (the lowest bought) 50,000 kilos or 50 metrical tons are required to contain 1 kilo of gold.

One *cien milesimo* equals $7.083 American gold per ton of 2000 pounds.

Milling.

As the lots are settled for, they are conveyed by tip-wagons to the ore bins, four of which (15 tons' capacity each) deliver between each pair of eight Gruson ball mills (No. 4). The pattern of the mill is too well known to need description. They are shown in Fig. 1, and at the top of the right-hand side of Fig. 2. The screens in use are of phosphor-bronze, 80 meshes to the linear inch, and the mill is charged with 1320 pounds of balls. Each mill requires 11 horse-power, and makes 25 revolutions per minute. The feeding is done by hand, requiring for the eight mills one man by day and one by night. Over considerable periods the output of ore has been 6.5 tons per mill per 24 hours, or, allowing for general stoppages and repairs, 1300 tons per month. The product, as might be expected, although passing an 80-mesh screen, is considerably finer. On the average, 60 per cent. of it will pass a 100-mesh screen. The mills give no trouble whatever, there being no manipulations in running them but the occasional patching of sieves and the renewal of worn-out grinding-plates, operations which are soon learned by an ordinary workman of fair intelligence. A mill, starting with new plates and screens, will run on the average for four months' constant work, at the expiration of which the buckle-plates (those upon the inside circumference of the mill) are worn out and have to be replaced. All renewals are of "Gruson special malleable steel," and are imported from the Gruson Company's works in Germany. The wear of steel from plates and balls amounts to 5.69 pounds per ton of ore ground, of which 75 per cent. is abraded, and the balance is contained in the worn-out plates, bolts, etc. The

fineness to which the ore is ground has been proved by trial to be the most suitable from a commercial point of view by reason of the fineness of the gold, and its perfect contact with the quartz, which enables even small particles of the latter to incase the precious metal completely.

From the hoppers under the mills the ore is discharged into sacks, which are run by a tramway, employing two men by day and two by night, to the sides of the amalgamating-pans. As far as the writer knows, where hard ore has to be ground fine and dry, there is no better mill in existence than the Gruson for reliable and severe service.

Amalgamation is conducted in pans (Fig. 2), of which there are 22, each 5 by 3 feet in size, lined with $\frac{1}{8}$-inch amalgamated copper plates, from 6 inches from the bottom to within 6 inches of the top. They are geared from the bottom; have iron mullers and shoes (originally intended for grinding), and make 48 revolutions per minute. The tops are covered in, the ore being charged through hoppers, provided with bars at the lower end, to prevent stealing. Each has 4 discharge-holes; the lowest slightly below the bottom (for which a slight canal is cast in the iron bottom of the pan); the next about 8 inches from the bottom, and the remaining two equally spaced. The three top-plugs are boxed in, and moved by iron handles running through the side of the housing, to prevent theft by discharging portions of the contents while running thick. For the same reason, the discharge-canals leading to the agitators are covered. The bottom plug is covered by a padlocked iron cap, and is only used when cleaning-up.

Each pan is charged with 88 pounds of mercury, and the ore is added in lots of 1100 pounds, with sufficient sea-water to form a pulp of such consistency that the mercury is broken up and distributed in fine globules all through the mass, which occupies in this state about one-third of the pan. After revolving thus for three hours, more or less, according to the nature of the ore, the amalgamation is complete of both the gold and the silver—the latter being aided by the salt-water, which is warm (being cooling water from the condenser). The pan is then filled with water and run for an hour, which allows the mercury to settle to the bottom and adhere to the plates. The plugs are then removed one at a time (top first), and the

ore is discharged into agitators, one serving for eight pans. These agitators are pans 5 by 5 feet in size, lined with copper plates. The discharge enters at the bottom and overflows at the top. Practically the whole of the mercury and amalgam remain in the first pans, which are ready for another charge of ore (the mercury being renewed only when the clean-up is made, while the agitators are cleaned out only once a month).*

The clean-up takes place once a week, when the pans are washed out by a second filling with sea-water, the covers removed, and the plates scraped to remove the amalgam, where possible, with steel scrapers. The same process is employed on the iron mullers, where a considerable amount of amalgam takes a firm hold in clusters, probably due to the precipitation of copper upon the iron from ores received from time to time containing small quantities of that metal. The muller is then set revolving; the bottom plug is opened, and the contents are run off and washed out into a bucket placed to receive them. The mercury is cleaned, strained through finely woven drilling, retorted, and smelted. The average assay of the bullion is, gold, .516; silver, .358.

The copper plates are cleaned each week and dressed. Every six months a general clean-up is made, when all the amalgam possible is removed, of which there is a considerable amount, varying according to circumstances, but at times reaching to $15,000. The locking-up of this value during the intervals is one of the chief drawbacks to the system pursued.

As far as possible all ores containing ingredients injurious to amalgamation are worked apart, and their treatment is varied according to their contents. For ores containing scorodite (hydrous ferric arsenate), which form a large proportion of the total, the addition of small quantities of caustic soda to the charge has been found to give the most satisfactory results.

After leaving the agitators, the pulp, which assays on the average 1 *cien milesimo* ($7.08 per ton), passes through *spitzkasten*, the concentrates from which (assaying about $14.16 and forming about 15 per cent. of the total) are dried in the sun and returned to the mill, while the balance, after passing over blanket-strakes 8 feet long (which just collect sufficient to

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* The loss of mercury amounts to about 0.25 pound per ton of ore worked.

pay for their trouble), is discharged into a sump connected with a centrifugal pump, working "drowned," by which it is elevated to a sufficient height to run by launders to the tailings-heaps, where, by means of dams, the finest slimes are got rid of and sent to sea. The tailings average $5.66 per ton, and the actual extraction in bullion, on ore the average assay of which is $41.68, may be taken at 86.5 per cent.

The mill is driven by a Corliss horizontal engine developing 150-horse-power, and two Lancashire boilers, 28 by 8 feet in size. Australian coal is used, being found more economical than the native lignite. The average consumption is 374 pounds of coal per ton of ore worked.

The Cyanide Plant.

This plant (Figs. 3 and 4) was erected by the writer to treat the dumps already in existence, as well as future tailings. The system is the McArthur Forrest process; the Cassel Company holding the patent for the use of cyanide in this country. The plant consists of six leaching-vats 18 feet by 6 feet 6 inches in size, mounted on a common foundation made of three stone-walls tied together by cross-walls (the plant being right on the sandy beach). The vats (Fig. 4) are filled from an overhead railway, to which the tip-wagons are raised by means of an elevator, and, after being discharged, are run down an incline by a brake; the continuous round allowing any number of cars to be operated at one time. Each car is weighed before lifting, and lime is added (roughly, 5 pounds per ton). The charge of a vat is 45 tons, onto which, after it has been leveled, is run 10 tons of caustic wash, containing 0.05 per cent. of caustic soda and 0.01 per cent. of cyanide of potassium. This is allowed to percolate, pass the zinc-boxes, and leach dry—which occupies about twelve hours. Twenty tons of strong solution (0.3 per cent. cyanide of potassium) are then run on, and leaching is kept up for four hours, after which the liquor is run through the boxes. As soon as the charge appears above the surface of the solution, 10 tons of weak wash (0.1 per cent. cyanide) are added. Lastly, 5 tons of water are run on, and the charge is allowed to leach dry, the last of the water-wash giving 0.01 per cent. of cyanide.

There are 3 zinc-boxes, 10 feet 9 inches by 2 feet by 1 foot 5

inches in size, each divided into eight compartments. The total charge of zinc per box is 70 pounds. The solutions are run through at about 3.3 gallons per minute per box, and assay in gold, on the average, entering the boxes, for the caustic wash 0.28, for the strong solution 0.8, and for the weak wash 0.25 part per hundred thousand. On leaving, all the solutions assay closely 0.1 per 100,000. The boxes are cleaned out every ten days by washing in the ordinary way; the slimes are discharged into a sump, from which they are pumped into two bags, each 5 feet by 1 foot 6 inches in size, made of drilling and covered with strong sacks to withstand the pressure. Through these the solutions filter quite clear, and are returned to the caustic-wash sump. The slimes, which contain about 29 per cent. of mercury, are pressed and retorted, after which they are smelted with borax, bicarbonate of soda and a small quantity of sand, which modifies the action on the plumbago pots. The bullion so produced is made into bars, which assay on the average, gold 19, silver 21, copper 59, and zinc 1 per cent. Through the whole of this process, as in the amalgamation, sea-water is used, and answers as well as fresh water. On starting, a rather heavy precipitate was formed of magnesium hydrate and carbonate by the caustic soda, both added and contained in the cyanide; but now, as the quantity of sea-water added is comparatively small, this precipitate is hardly noticeable. In consumption of cyanide there is practically no difference between the use of sea- and that of fresh water, while the entire absence of fresh water in the district makes it imperative to use salt-water where large quantities have to be consumed. The capacity of the plant is 1500 tons per month, the consumption of cyanide 1 pound per ton; the average assay of the tailings treated is $6.37, and the extraction of gold is 80 per cent.

After the leaching is finished the discharge-doors are opened; small holes are dug down to them through the tailings, and the charge is sluiced out, by means of a stream of water under 20 pounds pressure, through a 2.5-inch nozzle (from a Tangye pump); the tailings and water being conveyed by launders to the sea. In this way two men can discharge a vat easily in two hours. The plant employs one foreman, one night watchman (who is also engine-man), eight laborers charging and dis-

charging vats, one engine-man by day, one man on zinc, etc., and one boy, apart from the staff, whose services fall both on this department and on that of amalgamation.

The Occurrence of Tin-Ore at Sain Alto, Zacatecas, with Reference to Similar Deposits in San Luis Potosí and Durango, Mexico.

BY EDWARD HALSE, PUERTO BERRIO, COLOMBIA, S. A.

(California Meeting, September, 1899.)

THE tin-deposits of Durango, Mexico, have been ably described by Mr. W. R. Ingalls in a paper published in our *Transactions* in 1895.* While the occurrences of tin-ore in other parts of the Republic are similar in many respects to those in Durango, there are noteworthy local differences which, it is hoped, may lend interest to the present paper.

The deposits examined by me in May, 1895, are found in the Serrania de Chacuaco, Municipality of Sain Alto, District of Sombrerete. The workings are situated in a range of mountains having a general northwest to southeast trend between Sombrerete and Fresnillo; the most northerly claim (La Desparramada) being about six leagues southeast of the former town. El Refugio lies about four leagues to the southwest, and El Calabrote eight leagues to the west, of Fresnillo. The claims are from about 8425 to 8775 feet above sea-level, and from 1500 to 1800 feet above Sain Alto, the position of which town is marked in the map printed in Mr. Ingalls's paper.

In order to reach the claims, one uses the carriage-road from Sain Alto to the small tin-colony of Las Cuevas; from the latter place to the mines there is only a rough mule-track.

The mountain range consists of a rugged, weathered, gray granite rock, remarkable for large grains of quartz, and is flanked by masses of rhyolite and rhyolite-tuff of upper Tertiary age. The whole formation is broken up by narrow and steep winding *arroyos* and deep *barrancas*, mainly the result of denudation, and it appears to be a southeasterly extension of the tin-bearing belt of rocks north of Durango City. Here and

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* *Trans.*, xxv., 146; see also xxvii., 428.

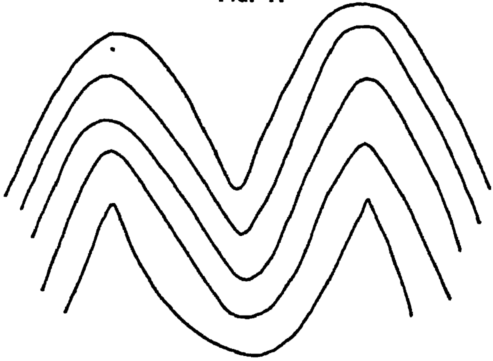
there patches of schist occur; but eruptive rocks largely predominate.

The granite is divided up by a series of nearly vertical joint-planes parallel to the main range (N.W. to S.E.), and is crossed at right-angles by a series of still more clearly-defined joints, while the rock is bedded or jointed horizontally as well—the result being that at the surface it is often weathered into curious prismatic columns, which give a peculiar topography to the district.

El Refugio.

These workings, situated in the depression of a hill having a general north to south direction, were a little over 30 feet in

Fig. 1.



Markings on Joint Plane at El Refugio.
¼ Natural Size.

depth, and had followed the main joints of the country (hard rhyolite), striking N. 20° W. to S. 20° E. and dipping W. 85°. These are crossed, almost at right-angles, by another series of joints. The main joints are stained red, and are filled here and there with reniform cassiterite from a knife-blade up to one or two inches in thickness. In many places the faces of the joint-planes are in actual contact. There is no appearance of a vein here. The deposit may be described as an occasional impregnation of rock-joints with tin-ore.

On one of the red joints the markings sketched in Fig. 1 are distinctly visible in one place, which appears to supply evidence of local crumpling in the country.

A few hundred yards away a small pit (*cata*) had been opened

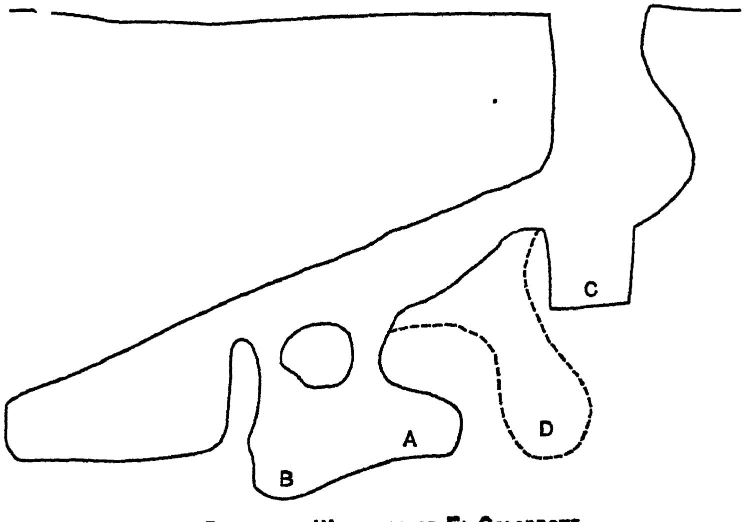
on a seam of reniform tin-ore, from one to two inches thick, and coursing in a general east to west direction. Clearly-defined joints seen here run northeast to southwest and dip northwest.

El Calabrote.

These workings (Fig. 2) were 50 feet in depth by about 63 feet in length, the general direction being E. and W., varying locally from E. 22½° N. to E. 33° S., and dipping S. 65° to 75°. They were very irregular in character.

The deposit appears to have the nature rather of a stockwork than of a single true vein. Several parallel veins are crossed

Fig. 2.



Profile of Workings at El Calabrote.
Scale. 20 feet to 1 inch.

by others, and generally contain some tin-ore, in reniform pieces, at and near the surface, and in more or less siliceous crystalline layers lower down. The country-rock is a reddish rhyolite, hard on the hanging-wall, soft and somewhat altered on the foot-wall, and here and there changing to a soft whitish rock. In one place (B, Fig. 2) two soft parallel veins, each about one foot in thickness, are separated by two feet of altered rock. A sample from here assayed 0.6 per cent. of coarse tin. At A a vein from 4 to 12 inches thick, consisting of brownish crystalline layers, was sampled and yielded 20 per cent. of coarse tin. The vein courses E. 22½° N. and dips to the south,

while the rock-joints (termed *cuartones* by the miners) trend N. 22½° E. and dip 66° E.S.E. At C a similar vein from 8 to 10 inches wide is seen going down in hard rhyolite. A sample yielded 11.6 per cent. of coarse tin. Nearly vertical joints cross the deposit here having a northeast to southwest trend. At D two veins are separated by rhyolite-conglomerate.

The ore in these workings is associated with almost pure white kaolin, sometimes flesh-colored and sometimes having a yellowish tinge. The cassiterite occurs as black specks in red jasper or in white opaque quartz, or in variously-colored siliceous and ferruginous layers (brown, yellow, white, black, red and chocolate-colored). Cassiterite in distinct crystals could not be detected.

The tin-ore occurs not only in veins and joints, but also as black patches in the country adjacent thereto, probably filling small cavities in the rock. In washing *tierras* (fine stuff) from the vein and adjacent walls, small rounded pieces about the size of peas are found, black outside, but formed of brown and yellow layers within. Fine yellow tin-ore (*metal acopolado*) is also obtained in washing the *tierras*.

The tin-ore, as already pointed out by Mr. C. W. Kempton,* would appear to have been deposited by preference at the points of junction between the so-called veins (probably in reality fault-planes) and the rock-joints.

La Desparramada.

This claim was so named from the numerous *scattered* reniform fragments of tin-ore found on the hill-sides below the workings.

The general direction of the deposit is N. 38° W. to S. 38° E., but it has a somewhat serpentine course. The dip is N.E. 75°.

It was opened to about 50 feet in length and 40 feet in depth. The country is rhyolite-tuff, softer near the vein, and with joints crossing the latter in a N.E. to S.W. direction and dipping S.E. 68° to 73°. The vein contains much feldspar, quartz, and some black specks (probably cassiterite). At one point the vein is 30 inches thick, and a sample yielded only 0.2 per cent. of coarse tin; at another point, a little higher up, it is 36 inches thick and gave only a trace of tin.

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* *Trans.*, xxv., 997, Atlanta Meeting, October, 1895.

The ore occurs in small black reniform pieces (*riñones* or kidneys), and as fine red oxide, associated with feldspar, quartz and micaceous iron.

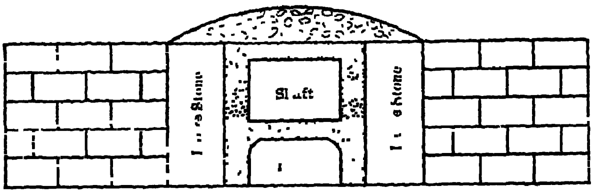
El Naranjo.

This is an old opencast on a hill on the southeast side of the same *arroyo*. The deposit strikes N.W. to S.E. and dips S.W. 75°, and is soft and of a red color like the last. It shows in places on the hanging-wall 18 inches of highly-colored rock containing streaks of soapstone, and kidney-shaped pieces of tin-ore and micaceous iron. This is said to be a very old working. The bottom being covered up, it could not be examined properly.

Las Cuevas.

This place is a small colony of tin-searchers ([illegible]) and smelters. Alluvial tin-ore is found on the slopes and along

Fig. 3.



Plan of Tin-Smelting Furnace.
Scale 2 feet = 1 inch

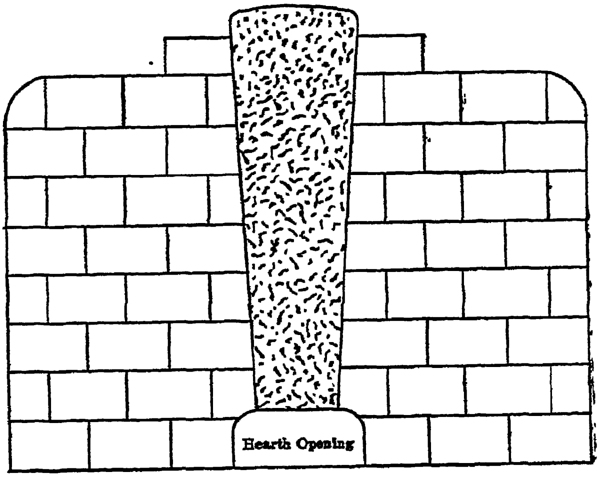
the bottom of the various *arroyos*, and is extracted by simply removing the overburden and washing the tin-bearing layer in *bateas*. The tin is usually collected after heavy rains, and consists of reniform and botryoidal pieces, varying in size from that of a pea to beautiful specimens of wood-tin (termed *hueso* by the [illegible]) several ounces in weight.

As the *arroyos* are numerous, run in various directions, and are, moreover, steep, narrow and winding, no large quantity occurs in any one spot. It is said that about 500 *cargas* (or about 62½ tons, taking a *carga* at 250 pounds) per annum are brought in from the surrounding districts and are smelted in Las Cuevas. By far the greater proportion is received during and directly after the wet season, or from July to December.

The ore is smelted with charcoal in rough stone furnaces, from 4 to 6 feet in height. Figs. 3 to 5 are from sketches

made of a furnace 4 feet in height, 6 feet in length, and from $1\frac{1}{2}$ to 2 feet in width. The center and back of the furnace are formed of uncut stones and clay, the shaft itself being well lined with the latter. The front and sides are built of stones and mortar. The shaft at the top is strengthened on either side by a large stone reaching from front to back (Fig. 3). The shaft measures 12 by 9 inches at the mouth, diminishing to about 6 inches square just above the tuyeres, while at the

FIG. 4.



TIN-SMELTING FURNACE.

FRONT ELEVATION.
Scale: 2 feet = 1 inch.

tuyeres it is 8 inches square. The hearth-opening measures 12 by 6 inches.

The tuyere-opening is 4 inches in diameter, and is placed about 10 inches above the base of the furnace.

The blast is produced by a double leather bellows* worked by hand (Fig. 6). Two tuyeres are used, 44 inches long. The ends projecting into the furnace are of iron, 8 inches in length. Above this they are of wood, covered with ox-hide for a length of 30 inches.

The tuyeres slope downwards, and can be moved so as to

* At Tepezalá, in the State of Aguas Calientes, similar double bellows are used for supplying blast to small copper-smelting furnaces, and are there termed *guijola*, according to Señor Santiago Ramirez.

impinge on the tuyere-openings at the back of the furnace (see dotted lines, Fig. 6).

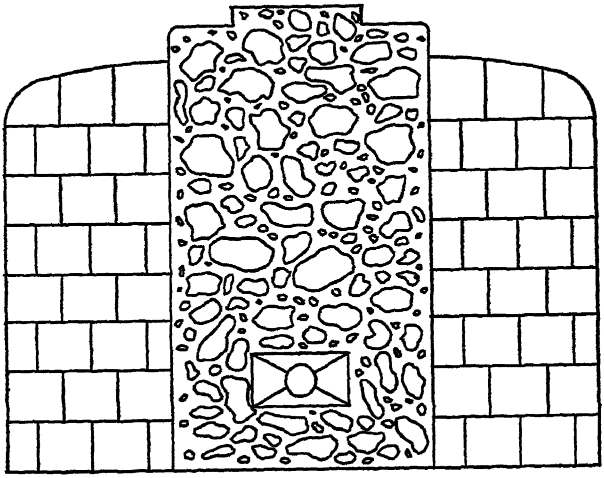
In 1895 alluvial tin-ore was purchasable at 9 cents (silver) per pound on the hills, or at 12½ cents placed in Las Cuevas.

At Sain Alto, white tin could be bought at $20 (silver) per quintal, or $400 per short ton.

San Luis Potosí.

For the sake of comparison with the above, I give an abstract from a report by Señor Jesus P. Manzano, a Mexican engineer, written in 1890, and published in 1893.*

Fig. 5.



Tin-Smelting Furnace.
Back Elevation - Tuyere Side.
Scale: 2 feet = 1 inch.

"Tin ore occurs in the mining zone of Santa María del Rio, 22 kilometers southwest of the city of San Luis Potosí, on ranges of hills which are from 1866 to 2816 meters above sea-level. The country is a trachytic porphyry (rhyolite?), sometimes exhibiting a columnar structure and sometimes bedded. In the neighborhood of the tin-deposits dikes or small masses of vitrophyre are invariably met with; hence the latter rock becomes a useful guide to their discovery. The ore is found in four different ways:

"1. In veins with gangue, or in separate kidney-shaped pieces (*riñones*) as incrustations, or in nuclei of chalcedony or cacholong.

"2. As *stickings* within the walls of the vein (en las *pegaduras* producidas en las relices por la sublimacion estanifera del interior).

"3. In conglomerates filling holes and cavities in the rock.

* *Boletin de Agricultura, Mineria é Industria*, 1893, pp. 91–107.

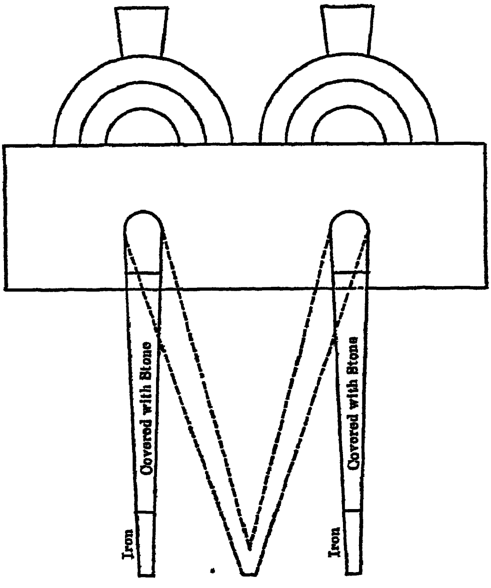
"4. In gullies or on the slopes of hills, kidney-shaped, fragmentary or earthy, and forming a kind of placer.

"The tin occurs alone, or is accompanied by micaceous iron, red hematite, topaz, etc. When the ore is nearly pure it is called 'metal de correa;' when hematite predominates or is present in equal quantities, it is termed 'plomillo.'*

"The Veta Honde, in the Hacienda de San Pedro (to the south of the zone), has been proved to a depth of 40 meters, 60 meters to the east and 40 meters to the west. The vein is 0.42 meter thick. In the Hacienda de Santiago the Rincon Grande vein is 0.2 meter thick. It has been worked 45 meters deep and 12 meters horizontally, and produced in 1882 more than 44,000 kilogrammes of ore.

"In the Loma de Pedernal, tin occurs in a rock which also contains gypsum, in layers 0.012 meter thick, on an average.

FIG. 6.



DOUBLE LEATHER BELLOWS AND TUYERES.
Scale: 2 feet = 1 inch.

"A short distance to the east of the Iglesia del Desierto, northeast of San Luis Potosí, deposits of bismuth and steatite are found with tin stone.

"In the Hacienda de Bledos, one Zavalo, a peon, exploited tin, and in a few years made a capital of $50,000 (silver).

"The vein of the Boquillo mine, in San Pedro, now being worked, has a thickness of 0.02 and 0.29 meter, and has produced at its best time 250 *arrobas*, or 2750 kilogrammes of ore in one week.

"One Garcia exploited three mines, long distances apart, and in six months raised from 400 to 500 kilogrammes of metallic tin.

"The ferruginous ore on an average yields 25, and the best ore from 35 to 80 per cent. of cassiterite."

* In the State of Mexico *plomillos* is the name given to particles of lead in slags.

POTRILLOS, DURANGO.

Mr. Ingalls has given a very complete account of the occurrence of tin-ore at Potrillos, Durango, but, in citing the literature of the subject, appears to have overlooked a report written in 1891, and published in 1893, by Señor Cárlos Patone, a Mexican engineer.* The following is an abstract of that report:

The country is a granitic or white porphyry of a relatively soft consistency, and is the rock called *piedra acanterada* in the State of Durango. (Mr. Ingalls has shown that the country is rhyolite and rhyolite-tuff, principally the latter.) The tin-ore is found in the veins as rounded masses from one or more grammes to many kilogrammes in weight. These kidney-shaped masses (*gulijoles* of the *gambucinos*), carried by the waters and deposited in the hollows and cavities of the *arroyos* and lower parts of the valleys, are known as placer-tin, arroyo-tin or kidney-tin (*estaño de riñon*). Elsewhere, the cassiterite is intimately mixed with crystalline oxides of iron, and sometimes penetrates the whole mass of the porphyry [illegible] to the vein, converting it into a very friable rock. The two last forms the *gambucinos* call *estaño de polvorilla*† or *polvorillo*. Up to date the *gambucinos* have only worked the *gulijoles* or coarse *polvorilla* varieties. In some mines (*e.g.*, San Miguel) the tin is associated with a large quantity of wolfram; in others occurs ruby-tin or durangite, in crystals of a beautiful red color.‡

In general the veins are of small thickness, commonly only a few centimeters, and are termed *hilos* (threads) by the miners.

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* *Boletin de Agricultura, Mineria é Industria*, 1893, pp. 108–123.

† In Zacatecas, as well as in Bolivia, South America, *polvorilla* is the term given to finely disseminated argentite (*plata negra*); at Cerro de Paseo, Peru, it is used for any dark, powdery kind of ore rich in silver; at Tamaya, Chile, *polvorilla*, according to Fuchs and DeLaunay, is a highly-ferruginous pulverulent matter of a dark color, containing small particles of phillipsite, forming the filling of the copper-deposit near the rich portions. At Peras, Oaxaca, Mexico, the name is given to altered marcasite containing some gold. In Spain the term *polvorilla* is frequently applied to rich ores of a soft nature; the names *polvillos* and *polvillones* are similar. The first two words are simply diminutives of *polvora* (gunpowder) and *polvo* (dust) respectively; *polvillon* is an instance of the *augmentation* of a *diminutive*.

‡ Mr. Ingalls found no positive evidence of the association of wolfram with the tin-ore of Potrillos. He makes no mention, however, of the San Miguel mine referred to above.

In each locality various veins are met with, which rarely run parallel, but frequently cross each other in various directions. At the points of juncture, the veins increase in thickness to 40 or 50 centimeters, and sometimes up to 1 meter or more, the quantity of tin contained in the veins increasing in proportion. The dip of the veins (98 of which have been discovered) is very irregular, but rarely exceeds 60°. The general direction, with a few exceptions, is N.E. to S.W. The tin-veins are irregular, presenting no constancy in thickness, dip, or in quantity of ore. The percentage of tin varies from 1½ to 25, or even 30; but the abundance of the ore is nearly always in inverse ratio to the percentage.

In the recent publications of the Geological Institute of Mexico there is a brief reference to the tin-deposits. The following is a translation of the paragraph:

"Tin occurs in Mexico in small veins running through rhyolite. The veins appear to have been formed from lines of fracture produced by contraction, due to cooling, and to have been filled by direct emanation. The associated minerals are hematite, topaz, and, in some places, durangite—that is to say two minerals which contain fluorine, thus bearing evidence of the identity of the agent employed by nature in bringing tin to the surface in the same state of combination and at different and widely-separated geological periods, and always, be it remembered, in the most acid rocks of the two series of eruptives; in the ancient series tin appears in granite containing white mica, while in Mexico, where the most modern emanations of tin have taken place, it appears in rhyolite of the upper Tertiary."*

The Copper Queen Mine, Arizona.

BY JAMES DOUGLAS, LL.D., NEW YORK CITY.

(New York Meeting, February, 1899.)

THE Copper Queen mine was opened in 1880 by Messrs. Martin, Ballard & Reilly, and the first copper-furnace was blown-in on August 20th of that year. Prior to that summer nothing but prospect-work had been done on the Copper Queen and on a number of adjacent claims. In fact, it was a small deposit, not of copper-ore, but of cerussite, which still remains undeveloped, on the western slope of the Queen hill, which

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* *Boletin del Instituto Geologico de Mexico*, Nos. 4, 5, 6, 1897, pp. 234–235.

first tempted miners to the spot. To reduce this lead-ore, a primitive furnace was erected near a spring, now dry. The development, just then, of this and other copper-deposits in the southern Territories was due to the simultaneous arrival of the Southern Pacific and the Atchison, Topeka and Santa Fé railroads, though it was stimulated by the business revival of 1880, with the consequent rise in the value of copper.

The geology of the Dragoon and Mule Pass mountains, in which the Copper Queen mine is situated, has not been systematically studied. On the flanks of a granite core lie beds of limestone supposed to be Carboniferous, but possibly of earlier origin. Those to the west carry, either enclosed or as contact-deposits, the silver-bearing minerals which in the early '80's made Tombstone one of the most famous mining-districts of the West. The limestones on the eastern slope of the Mule Pass mountains carry the ores of the Copper Queen mine. The limestone masses appear to be broken and filled by extensive bodies of intrusive feldspathic rocks, which seem to have exerted a decisive influence on the genesis of the ore, though their relation to the ore-masses, whether these lie on the contact or are completely and deeply imbedded in the limestones, is a matter upon which theorists will differ. The feldspathic rocks to the east of the copper-bearing mass of limestones of the Copper Queen group are deeply colored superficially by oxides of iron, and, as recent explorations made by other companies than the Copper Queen show, carry iron- and copper-pyrites disseminated in particles and in bunches, but whether in profitable quantities or not has not yet been determined. The colored band of these adjacent rocks (which are supposed to be rhyolites, though their decayed character renders any determination of their original mineralogical composition doubtful) is broadest in contact with the Copper Queen and the Atlanta claims, where the largest bodies of copper-ore have been discovered in the limestones, and tapers towards the south, where the ore-bodies as yet found in the limestones are smaller and deeper. The contact of the limestones and rhyolites appears to represent the line of a great fault, which is also indicated by a marked depression in the surface.

Beneath this depression lie ferruginous clays, locally called "ledge-matter," enclosing masses of ore, both oxidized and un-

oxidized; but the rocks at this level are altered by decay to such a degree that it is difficult, if not impossible, to define the line between altered limestone and altered rhyolite. Where, however, the deep workings of the Copper Queen have penetrated the feldspathic rocks, the ground has proved to be barren. Nevertheless, since the wealth of other mining districts in Arizona resides almost exclusively in the so-called porphyries, exploration in the same class of rocks in the Warren district is a legitimate enterprise.

The successful development of the Copper Queen mine, however, has been confined to the limestone belt lying between what appear to be two prominent faults—the one already referred to, and another to the west of the Queen hill.

The outcrop of copper which was first attacked, and which was, in fact, the only extensive surface-indication, was on the northern exposure of a limestone hill. In this place stripping revealed a solid body of oxidized copper-, iron- and manganese-ore over 60 by 60 feet in area, and so rich in copper that the furnace, fed from the surface-ores alone, yielded for a few months 23 per cent. of metal. Fig. 1 shows a section through the open-cut made on this body, and Fig. 2 an outside view thereof. This large outcrop was enclosed in an almost circular unaltered limestone frame. Associated with the ore was an abundance of calcite; but the percentage of silica was so small that quartz had to be added to the furnace-charge. This body, retaining its general dimensions and well-defined limestone walls, dipped at an angle of about 30 degrees southeasterly into the hill. Between the 100- and 200-foot levels the ore changed into a clay, with well-marked bedding, too lean in copper-carbonate to be profitably worked; but below this zone of clay the copper, as carbonates and oxides, increased to 12 per cent., and was associated in a measure with limonite, imbedded in ferruginous clay. This ore-body extended to a depth of 400 feet on the incline from the surface, and there terminated abruptly in hard limestone.

The enrichment of surface copper-ores and their rapid impoverishment at a shallow depth is not an uncommon occurrence in the "arid region" of the United States. It probably takes place through the oxidation and precipitation, in this hot, dry climate, from the copper-solutions which rise to the

surface during the decay of the ore. A lower layer of ore is thus necessarily depleted, in proportion as the surface-layer is enriched. The insensible flow, through the apparently dry rocks of the region, of moisture charged with soluble salts is often evinced by the thick efflorescence of copper-alum which rapidly covers the walls of drifts run through or near feldspathic or argillaceous rocks, even when the copper-contents of these rocks are so low as to be barely appreciable. During the dry season a waste-heap of such refuse will be completely covered with a green coating.

On the other hand, in the wet eastern climate, as in Tennessee, the surface-ore, where it has not been denuded by glacial action, consists of insoluble ferric oxide deprived by lixiviation of the copper which, in Arizona, under favorable atmospheric conditions, would be fixed as oxides. The rapidity with which a soluble copper sulphate when exposed to the air is converted into insoluble basic sulphate, and this into more permanent compounds, is illustrated in many copper-regions of the Southwest, where copper-solutions ooze from almost barren [illegible] feldspathic rocks, and, on reaching the surface and filtering through the gravels, form copper-bearing conglomerates.

The first ore-body, above mentioned, was not exhausted until 1884, when it had yielded about 80,000 tons of ore and 2[illegible] pounds of copper. The earliest months of that year were the gloomiest which the district had known up to that (or, fortunately, up to the present) time. Simultaneously with the commencement of active operations on the Queen, a large group of claims on the southern slope of the Queen hill had been explored by the Neptune Co., and a furnace-plant had been erected by it on the San Pedro river, some miles distant. The reason for building the reduction-plant so far from the mine was the scarcity of water in Bisbee, which at that period was so serious that the Copper Queen occasionally had to damp its single furnace for lack of a sufficiency of water to cool the jacket. The Neptune Co., after expending its capital and bonded debt, suspended operations in 1882. Another corporation, the Atlanta Mining Co., owning claims adjacent to the Queen, had been searching in vain more than three years for an ore-body by following, to no profit, surface-indications. Other minor operations of a like kind had been equally unsuc-

cessful. At that date the Queen Co., having reached the bottom of its ore-body and the 400-foot level of the incline, could count only some three months' ore in sight; and the Atlanta had decided to abandon the enterprise after one more effort should have been made to discover ore. The foot of the Queen incline, which coincided with the bottom of the original Queen ore-body, had nearly reached the side-line of the claim, and therefore a drift easterly along the side-line in hard limestone was the exploratory work undertaken by the Queen—a long drift having been previously run to the west without encountering any ore.

Meanwhile the Atlanta Co. was sinking a shaft in barren limestone a little to the south of the point towards which the Queen drift was directed. Thus, final pieces of exploratory work were under way, prior to the abandonment of their property by both companies, when, almost at the same time, each of them struck a new ore-body which appeared to be dipping northwest, or in a direction the reverse of that of the body originally discovered. The two companies then wisely decided to consolidate on equitable terms, rather than waste their funds in obtaining a legal interpretation of an even more complicated problem than that involved in the Richmond-Eureka "apex" case. Since then the claims of the Neptune Co., the Holbrook and Cave Co., the Silver Bear Co. and a number of private owners have been acquired. Many of them have proved to be barren, but not a few contribute their quota of ore to the total of the consolidated company's product, which is drawn at present from what would be some twenty different unprofitable mines, if each were under separate management.

The first ore-body extracted extended from the surface to the original 400-foot level of the old incline, which corresponds to the 200-foot level of the new Czar shaft. The second ore-body, discovered about 600 feet east of the first, was covered at the surface by 200 feet of limestone, and abruptly terminated at a depth of 300 feet from its apex. A narrow seam of ore was known to extend into the limestone to the south of the original ore-body, but it was not followed until years after its discovery. Then it was found to be the connecting-link between the ore-body from which it sprung and another, still larger, in the southwest of the Atlanta claim. This ore-body extended in

depth from above the 100-foot to below the 300-foot Czar level, and on the sill-floor of the latter level the stope was 200 feet by 150 feet—by far the largest opening made in any ore-body. As it was of such magnificent size, we thought ourselves safe in running a long drift for 1500 feet, through limestones, from the Czar shaft, to strike it on the 400-foot level. (See Fig. 1, giving cross-section No. 25.)' On reaching the position which the ore should have occupied, none was found, nor has the extension of the ore-body in any direction been discovered by diamond drill-holes bored radially for thousands of feet. A drill-hole pointed upwards entered the ore at 30 feet below the 300-foot level, where the ore abruptly terminated.

Disappointments of a like character have beset operations in other sections of the mine. A large ore-body in the southern section of the mine was traced downward to a point 40 feet below the 400-foot level. A search in all directions on the level below has failed to find it. Where ore-bodies are so eccentric in their size and the direction of their curves, it is often well-nigh impossible to trace their extension, or be sure of their extinction, until they are being actually extracted. In searching for ore in these limestones, it is extremely difficult to interpret the signs which point to its presence, or to distinguish accidental occurrences from actual laws of deposition. The presence of ore in more than one place on the 500-foot level, and elsewhere in the southern portion of the mine, was indicated as probable by the presence of ore on the 400-foot level and the intermediate level below; but in no single instance has the ore been found on the 500-foot level where expected. In fact, nearly a mile of drifts was run on that level before any copper was encountered.

Certain general conclusions have been provisionally reached. There seem to be two series of limestone-beds, both of Carboniferous age: the upper bedding, recognized as the white; and the lower, as the blue—though this distinction of color is not always well marked. They dip conformably to the south, but at varying angles. At some places they lie almost flat, at others they attain an angle of over 30 degrees. The large masses of copper, whether oxidized or unaltered, have as yet been discovered exclusively in the upper series, and only at the base of that series. Its total thickness is probably about 1100

feet, but only in the lower 300 feet has ore been found in profitable quantity. Where the series is thickest, under the apex of the Queen hill, no ore-masses are known to exist. Large quantities of ore lie, as already described, under the valley where exists the obscure dividing-line between the limestones and rhyolite, and where the former are probably shallow; but the largest isolated ore-body yet extracted was separated by many hundreds of feet of barren limestone, and what is locally called "ledge-matter," from this contact.

As we work to the southward, the ore-bodies attain greater depth from the datum-line of the collar of the Czar shaft. No ore has been discovered below the 400-foot level in the northerly section of the mine, whereas in the section to the south, reached by the Holbrook shaft, ore-bodies have been found at 500 feet below that point, and still further south the ore attains a greater depth. But the ore-bodies hitherto encountered here are small in comparison with those explored and extracted in the northern sections.

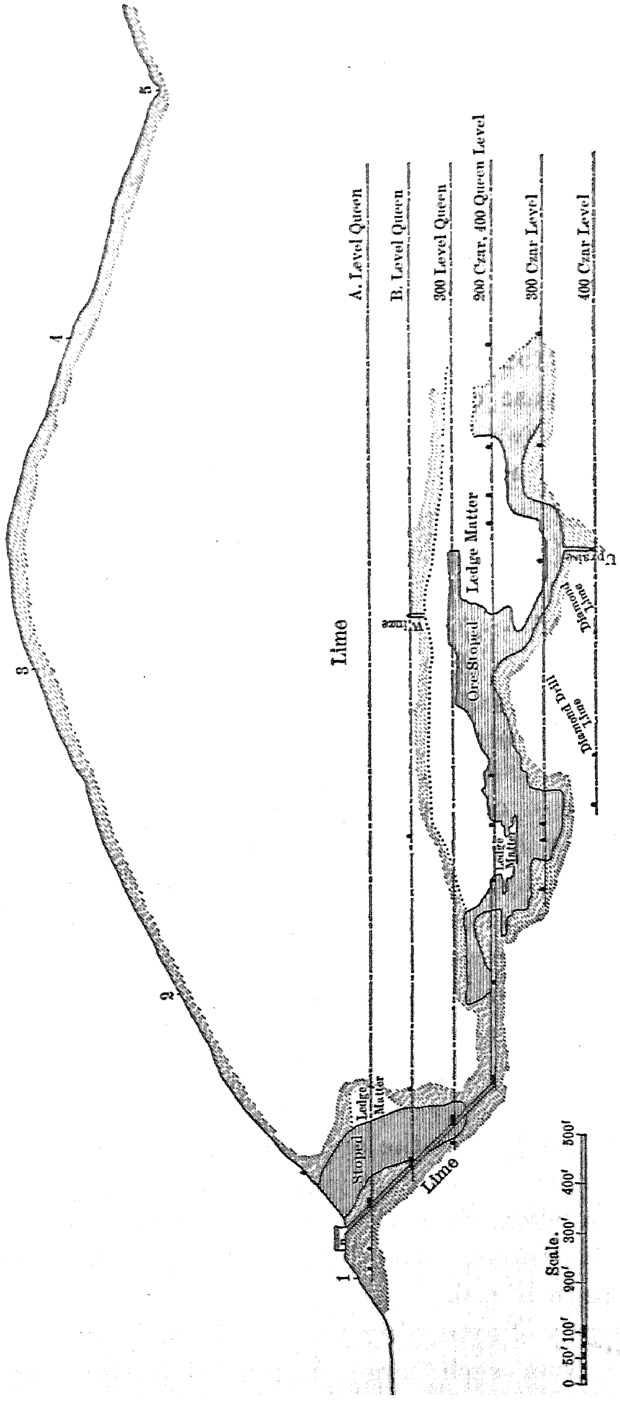
The conclusion that the profitable ore is confined to the upper series of limestones is based on the experience that large, compact ore-bodies have not been found to extend below a certain horizon. Nevertheless, the limestones of the supposed lower series, as far as they have been explored, are more thoroughly impregnated with iron-sulphides, associated with minute quantities of copper-sulphide, than the upper limestones. But so little work has been done below the upper chain of ore-bodies that no conclusive opinion can be formed as to the metalliferous value of the underlying limestones. There is slight probability of oxidized ore being encountered, but the general dissemination of pyrite and chalcopyrite in fine grains through the rock leads to the hope that areas of ground may be entered where the latter mineral may be abundant enough to render the limestone a "concentrating-ore."

The Copper Queen mine has become famous for its beautiful specimens of carbonates, both malachite and azurite. The malachite is never found in such large and compact masses as to make it commercially valuable for decorative purposes; besides, occurring generally in thin botryoidal masses, it is usually streaked with manganese, which detracts from its purity. Its most striking mode of occurrence is in geodes, which are lined

with velvety crystals of the same mineral. These hollow spheres, the walls of which are composed of concentric layers, are rare, but, when found, are usually in nests imbedded in soft, wet, ferruginous or manganiferous clays, such as constitute the gangue, or "ledge-matter," of nearly all the ore; and they occur at no great distance from a limestone wall or partition. The slabs of azurite, also, usually occur near limestone, but preferably in the manganiferous, clayey gangue. The oxidized copper-ores, however, which are mined in economic quantities, consist usually of cuprite and carbonate, disseminated through limonite; or of carbonates, chiefly of the green variety, in streaks or crystals scattered through ferruginous or manganiferous clay; or of minute particles of metallic copper, with more or less cuprite crystals, disseminated through yellow clay. These yellow clays are generally more distinctly bedded than the masses of red and black clays which carry the highly oxidized copper-compounds. Masses of any considerable size of native copper are found almost exclusively, not at the surface, where the oxidizing agencies have been most active, but in the deepest layers of the large ore-bodies, where apparently some reducing-agent has been more actively at work than elsewhere, and where the ore is furthest removed from atmospheric interference. On the sill-floor of the 300-foot level (at the bottom of the great southwest ore-body already referred to), native copper was abundant in masses, some of them of several hundred pounds in weight. The surface of the native copper lumps and masses is always more or less perfectly crystallized, as of course is the case in those mines where all the secondary copper-ores were deposited slowly from the dissolved constituents of the original sulphides.

While selected specimens of the oxidized ores carry a very high percentage of copper, the percentage in the ore as actually mined is much lower, inasmuch as the particles of ore proper are, as explained, associated with clays or limonite; and these cupriferous clays or limonites are themselves embedded in vastly larger masses of clayey ledge-matter, absolutely barren of copper. The approach to the so-called ledge-matter, when drifting through limestone, is generally indicated by a softening of the rock and a gradual replacement of the lime by silicates of alumina. A series of analyses taken from a drift in

FIG. 1.



CROSS-SECTION NO. 25. COPPER QUEEN CON. MINING CO.

Section of the Copper Queen Mine through the Open-Cut and the Southwest Stope.

the eastern section of the mine, as an ore-body is approached, indicate the gradual change from unaltered limestone to clays, involving a decrease in lime from 24 per cent. to 0.33 per cent. and an increase in alumina from 2.20 per cent. to 16.9 per cent.

The further passage from altered limestone to ledge-matter is often less marked by change in composition than by change in color. Figs. 3 and 4, taken in one of the southwest drifts, show distinctly the contact and the sudden transition in color from pale limestone to deep-colored ledge-matter. The assays show the increase of the iron with the increased depth of color.

The altered limestone of Fig. 4 contains:

CaO.	MgO.	SiO_2.	Al_2O_3.	F_2O_3.	CO_2.
50.0	......	8.04	3.04	1.6	38

The subjacent ledge-matter:

CaO.	MgO.	SiO_2.	Al_2O_3.	F_2O_3.	CO_2.
1.62	5.98	53.9	14.0	14.4	6.85

The ferruginous clays, when entered, are regarded as hopeful indications of ore, but exploratory drifts are often made in them for many hundreds of feet before reaching a trace of copper. Suddenly, without any premonition, the clay carries copper; and as suddenly the drift runs again into barren ground. Large areas have been stoped from these sporadic masses, and the locality has been abandoned as exhausted, only to discover years afterwards that a mere partition of barren ledge-matter separated the exhausted stopes from still larger reserves.

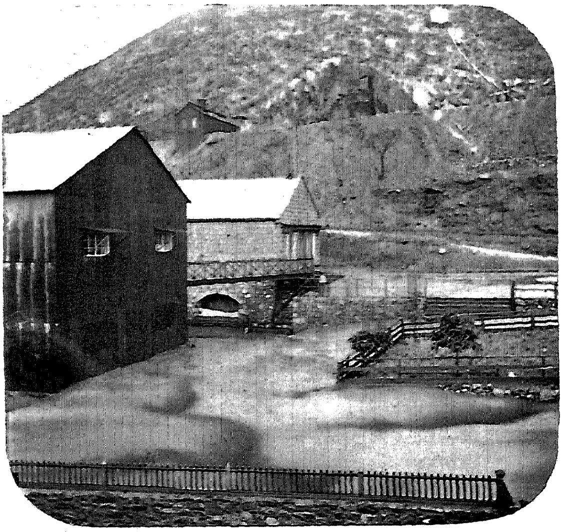
As at the surface in the open-cut, so occasionally in depth, the ledge-matter is in contact with unaltered limestone.

Fig. 5 was taken where the ledge-matter has parted abruptly from hard limestone. The ledge-matter is often very much contorted, as in Fig. 6.

The difficulty of extracting these comparatively small masses of soft ore from such large masses of plastic clay is very considerable. The whole hill is in a state of ceaseless movement. The comparatively shallow capping of limestone is fissured to the surface in all directions, and the lateral strains on

the partitions of limestones which separate the masses of ledge-matter, when large stopes are made in them, cause these partitions to yield. The slag-dump in the valley east of the hill (Fig. 7) rests on detritus, beneath which is ledge-matter, and is a source of considerable annoyance in the mine, as its pressure is continuously squeezing up the ledge-matter in the eastern stopes of the mine. And so soft is the ledge-matter which is under this valley, that cone-shaped caves extend to the surface from the stopes through 80 to 100 feet of barren clay,—but fortunately the movement of ground is slow, and ample warn-

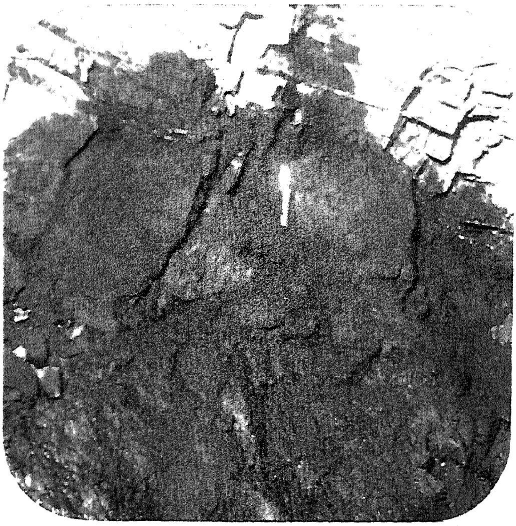
Fig. 2.



Open-Cut of the Copper Queen Mine.

ing is given. The tendency of the clays, under this pressure, is to rise, and therefore it is impossible to maintain a perfectly level track in the permanent ways. At the same time the walls of the drifts are either forced out of line by lateral pressure from one side or the other, or the drifts are contracted by the irresistible pressure, from all sides, of the swelling ground. Hence it is impossible to use underground the most economical modes of traction. The stopes can be held up only by timbering in square sets, and the face of the stopes can never be safely broken down ahead of the timbering. The yield of this class of ore is about 7 per cent., after rough selection in the

FIG. 3.

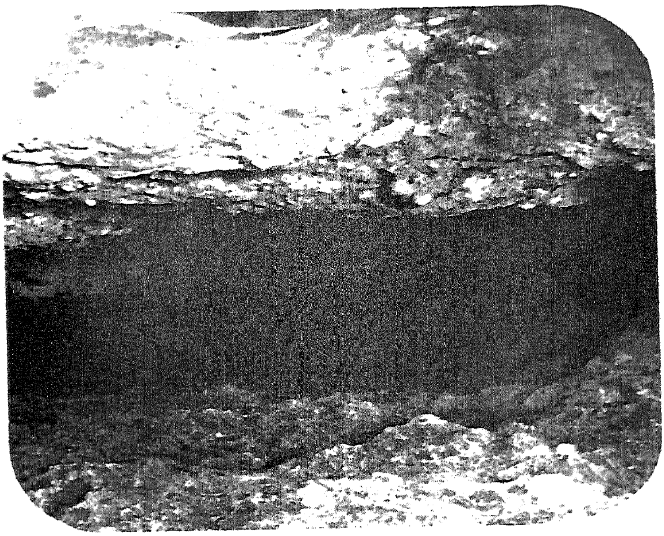


Contact of Altered Limestone and Ledge-Matter.

FIG. 4.

Contact of Altered Limestone and Ledge-Matter.

FIG. 5.

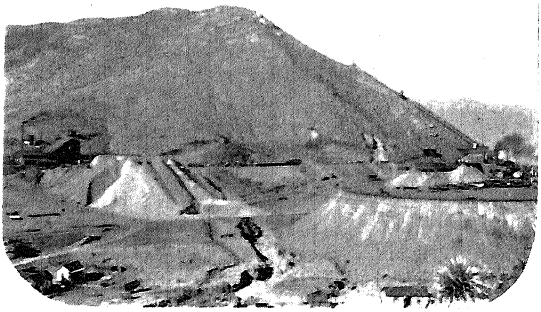


Parting of Ledge-Matter from Unaltered Limestone.

FIG. 6.

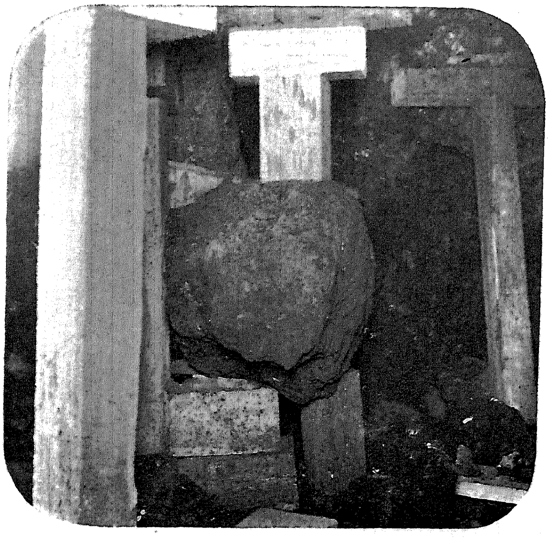
Contorted Clays in the Baxter Tunnel.

FIG. 7.



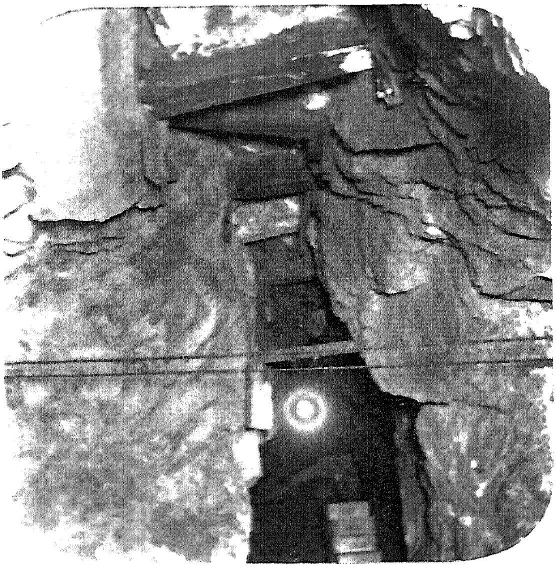
Slag-Dump East of Copper Queen Hill.

FIG. 8.



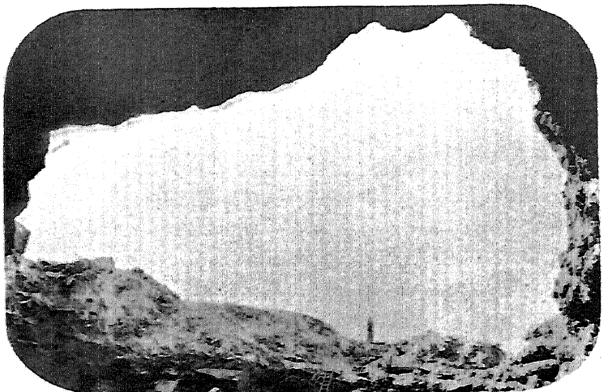
Limestone Boulder, Found Imbedded in Ore.

FIG. 9.



Fissure on the 200-foot Czar Level.

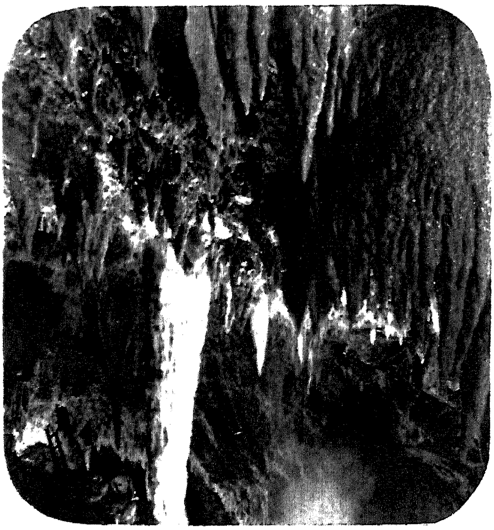
FIG. 10.



Open-Cut, from the Interior of Mine.

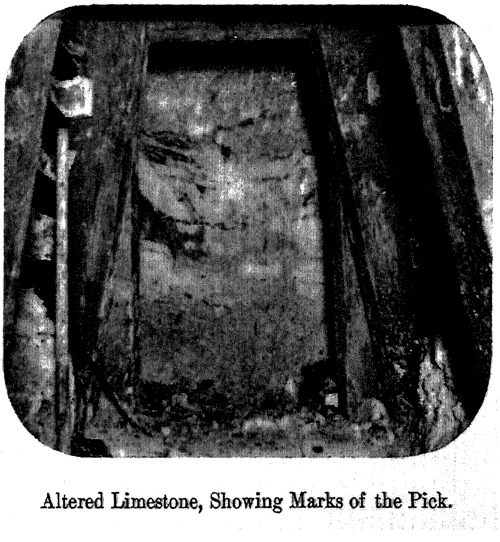
*

FIG. 11.



Stalactites in a Cave in the Copper Queen Mine.

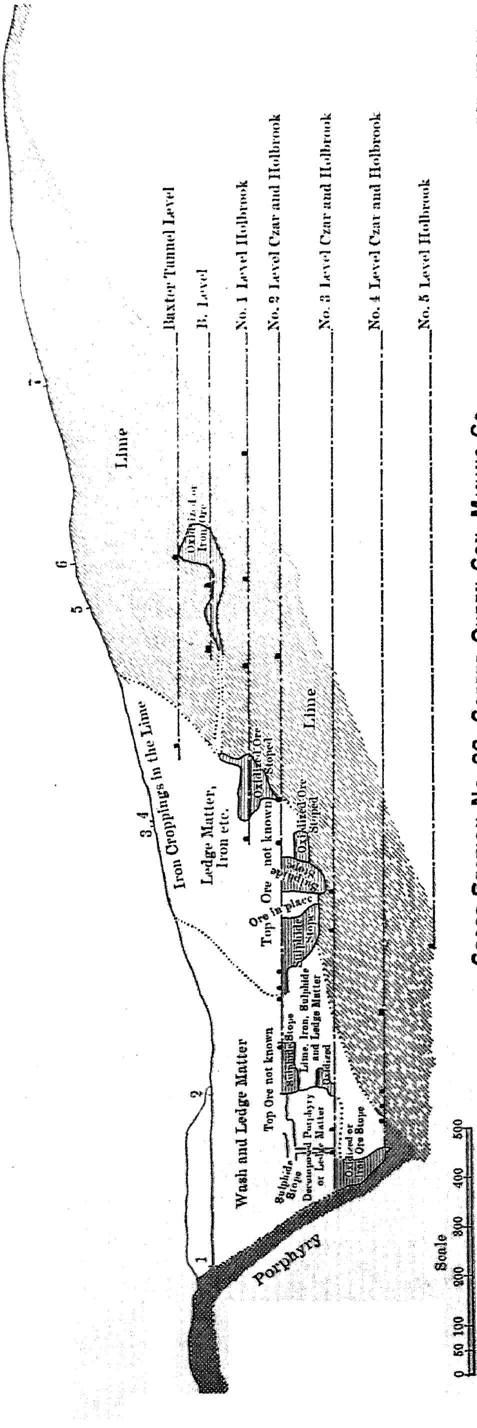
FIG. 12.



Altered Limestone, Showing Marks of the Pick.

*

Fig. 13.

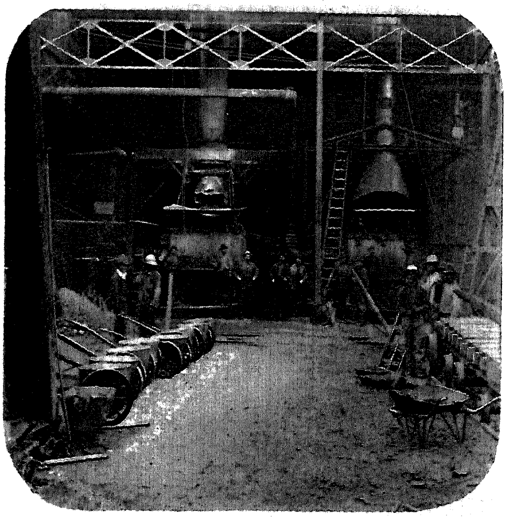


Cross-Section No. 23, Copper Queen Con. Mining Co.

FIG. 15.

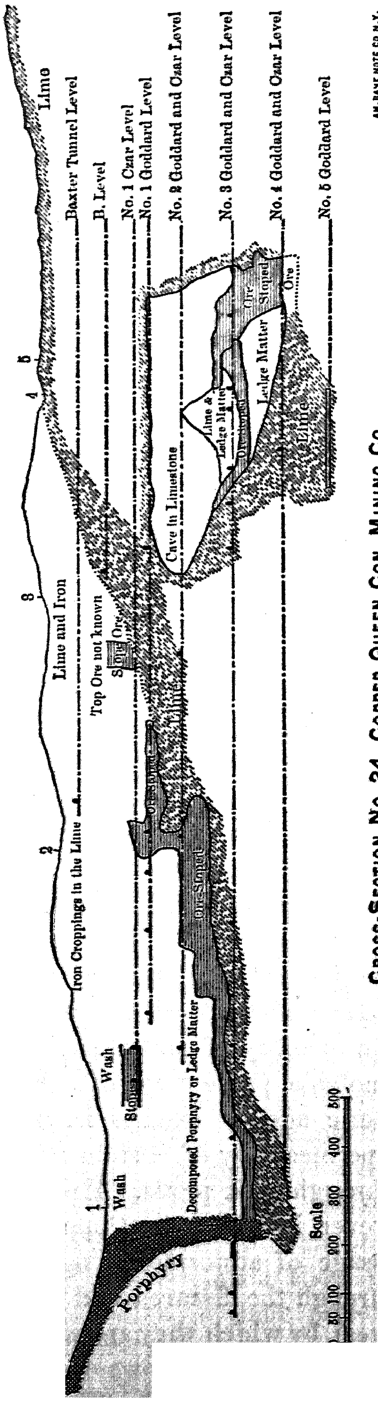
Tilting-Furnace Well.

FIG. 16.



In the Bessemer-Pit.

FIG. 14.



CROSS-SECTION NO. 24, COPPER QUEEN CON. MINING CO.

stopes, where about one-half the total material broken is rejected. To supplement the deficiency in filling up the stopes, barren ledge-matter from exploratory drifts is used. Though the timbering of worked-out portions of the stopes is thus enforced, so violent is the movement of the ground that, when an old stope is drifted through, the old timbers are found upset and dislocated or crushed into chips. The size of timbers usually employed in square sets is 10 by 10 inches and 12 by 12 inches, and the most available source of supply is Puget sound. About 30 feet, board measure, is buried in the mine to the ton of ore extracted.

A notable quantity of oxidized ore is also obtained from narrow irregular deposits between limestone walls, or from still more undefined bodies, which cement together limestone boulders, large and small. Fig. 8 shows a limestone boulder, which was imbedded in ore, and has been left in the stope, supported by timbers. These boulders are generally superficially gnarled and corroded, as well as decayed to a depth of several inches, and they and the ore entangled among them are never situated at any considerable distance from the solid confining limestones.

The depth to which decay of ore has extended from the surface is very variable. A very large body of sulphide-ore was struck on the 200-foot level, and yet in other sections of the mines the ore is partially oxidized to the lowest depth at which ore has been encountered, namely, 570 feet below the collar of the Holbrook shaft. Yet below the 300-foot level, completely oxidized ores became scarce. The furnace-mixture, for years before the company abandoned the making of bars direct, yielded a certain quantity of matte, and the copper bars were debased by a notable percentage of sulphur. The depth to which atmospheric agency reaches is, of course, determined largely by the permeability of certain rocks to the insensible flow of water through their pores. The compact carboniferous limestones, however, in which the Copper Queen mine occurs, permit the passage of atmospheric agencies to considerable depth, rather through the fissures and joints (expanding occasionally into caves), by which they are reticulated than through the pores of the rock. Fig. 9 shows one of these open fissures. An interesting phenomenon in the West, where the climate is

so extremely dry, is the great depth to which roots will strike down through rock-fissures in search of moisture.

The sulphurets in these limestones occur in layers of various thickness and solidity. When solid and thin, they are generally partially oxidized, and are rich. Two very large compact masses have been encountered, and in part explored. The largest apexes on the 200-foot level and has been traced to the 400-foot level, and a string of stopes nearly 500 feet in length has been opened upon it; but the profitable ore bears only a small proportion to the whole mass. Roughly speaking, the mass is enveloped in a shell of oxysulphide, and streaks of similar black copper-ore of good grade intersect it; but the core consists of compact bisulphide of iron, very lean in copper. The same condition holds good of most of the large iron-pyrites masses the world over, where oxidation is occurring; and, therefore, while estimates of quantity can generally be easily made, certainty as to value is more difficult to reach.

The genesis of these ore-bodies, the progress of their decay, and the contemporaneous changes wrought in the surrounding rocks, are interesting subjects of study and speculation. During the early stages of the mine's development, the opinion was prevalent, based exclusively on the clean-cut outline of the great outcrop and the well-defined cavity of limestone in which the first ore-body was enclosed (see Fig. 10, a view taken from within the mine, but through the open-cut), that the original unaltered ores, prior to their alteration, had filled caves previously formed in the limestone, and that this filling had been effected partly through infiltration and partly through mechanical action. The barren clays below the 100-foot level were distinctly stratified; and at still greater depths in these and other sections of the mine large, round, siliceous pebbles, isolated or in layers, are found. Further developments have shaken this hypothesis, though there is abundant evidence that, through cracks and fissures in the limestone, surface-detritus has been carried to considerable depth, and that mechanical as well as atmospheric agencies have played their part in creating and distributing the ore-bodies in their present secondary altered condition. Large caves exist in the hill. It is therefore conceivable that into pre-existing caves copper-solutions might have

entered concurrently with mechanically transported clays and gravels, thus forming the alumino-ferruginous copper-ores which constitute the great mass of the oxidized bodies. But the almost total absence of lime in these oxidixed ore-bodies is, in itself, a strong argument against the supposition; for had the copper been carried into them through infiltration from limestones, and with lime, the ores would have possessed the composition of the cupriferous stalactites, such as are shown in Fig. 11, which line the caves, and therefore would have contained a large proportion of lime as calcite. But this is not true, either of the ledge-matter or of the ores.

In framing a reasonable theory to account for the formation of the oxidized ore-bodies, we may start with the assumption that the copper they contain existed originally as a sulphuretted compound. Another assumption, which cannot be made with so much certainty, but which, I think, may be fairly allowed, is that the composition and distribution of the unaltered masses of sulphurets, which are contiguous to the altered ores, are identical with the composition and distribution of the now oxidized ore-bodies before decay had set in.

As I have already remarked, limestones contain more or less disseminated iron- and copper-pyrites, but these particles, protected from atmospheric action by the envelope of rock, are unaltered even at shallow depths. Not so, however, the large mass, for instance, of compact pyrites which extends from the 200-foot level to the 400-foot level. It exhibits every stage of decay, and the enclosing limestones are widely and completely altered. A section through this portion of the mine would exhibit the limestones becoming gradually softer and exchanging their lime for clay, while yet retaining the structure and color of the original rock. Fig. 12, from a photograph taken in this section of the mine, shows distinctly the structure of the limestone; but the hard rock is so altered that it can be removed by pick, the pick-marks showing distinctly in the picture. This altered limestone contains CaO, 7.1; MgO, 8.36; SiO_2, 27.1; Al_2O_3, 15.5; CO_2, 17 per cent. Immediately on it lies ledge-matter, the composition of which is CaO, trace; MgO, trace; SiO_2, 27.4; Al_2O_3, 15.1; F_2O_3, 33.9; CO_2, 10.6. The light, clayey, aluminous rock thus suddenly changes to a ferruginous clay, generally barren of copper. This envelope gives

place to a black sulphuretted ore of very diverse composition. At places it runs very high in copper, as indicated by the erubescite streak under the pick. At other places, though the same in appearance, it consists merely of an oxysulphide of iron. On the whole, however, this second shell contains the most profitable of the sulphuretted ores. It is not of uniform thickness, any more than of uniform composition, but thick enough to permit large stopes to be opened upon it. The kernel of the mass is very much leaner in copper than the shell, and consists of compact iron-pyrites averaging about 45 per cent. sulphur.

On the same horizon as this particular body of both partially altered and wholly unaltered pyrites, we have large quantities of ledge-matter, in which occur, as already described, great masses of cupriferous limonite, while, elsewhere in the same ledge-matter, we have areas of cupriferous clays. These differ from the barren ledge-matter in little else than the percentage of copper. The limestones, as ledge-matter is approached, have undergone substantially the same alteration as in the vicinity of the black oxysulphide.

Though, as a rule, the clays of the ledge-matter are ferruginous, they enclose, here and there, masses consisting of pure white clay, so free from iron as to be suitable for the plastic material of converter-linings. Such white clays may have been originally partitions of pure limestone between masses of sulphuretted ore, or blocks of limestone intercalated in the ore, which we assume the ledge-matter to have originally been.

If, therefore, we assume that the ledge-matter represents or replaces ore as originally deposited, in what condition was that ore, and through what process of alteration has it come to assume its present composition and appearance? It has been suggested that the ledge-matter is an altered feldspathic rock in place; that this intrusive rock carries the ore; and that the ledge-matter and the ore, as found to-day, are merely instances of alteration. It is difficult to conceive how irregular, isolated masses of intrusive rock could be injected into the limestone so as to fill the spaces occupied by the ledge-matter; but a more cogent reason for questioning the correctness of the theory is the fact that outside of, and below, the area of altera-

tion we find no such bodies of copper-bearing "porphyry" (to use the popular term) as the theory calls for; whereas we do find large bodies of unaltered copper-bearing iron-pyrites in contiguity with the altered bodies.

Fig. 13 is a cross-section through altered and unaltered ore-bodies.

One or more granite veins traverse the limestones of the Queen hill, and even cut through, without appearing to affect, the ore-bodies; but these veins are barren. They have not been traced from the surface, but they correspond approximately in position and direction with heavy quartzite croppings, which break through the limestones near the crest of the hill. If the surface quartzites and the deeper granites belong to the same system, this instance would confirm the evidence presented elsewhere, that feldspathic rocks, under such potent influences of decay as exist in the Southwest, lose all their basic ingredients at, or near, the surface, and are altered into very acid felsites, or even quartzites. We have used the decayed feldspathic rocks on the 400-foot level as plastic lining for the converters.

With regard to the ledge-matter and the oxidized ore, my own opinion is that they are the product of replacement and local concentration; that where there is ledge-matter to-day, there was, originally, more or less compact iron-pyrites carrying a small percentage of copper; and that, during the process of alteration, not only did ferruginous solutions of alumina replace the pyrites, but the copper, by a process of segregation akin to crystallization, was concentrated and collected into areas of limited size, thus constituting the comparatively small bodies of oxidized ores which are disseminated irregularly through the very large masses of ledge-matter. The acid-products of decay thus liberated must have been enormous. As the outline of the masses of ledge-matter has never been traced, it is impossible to determine their actual size, and thus arrive at an accurate estimate of their quantity; but, approximately, there has been exposed on all the levels above the 400-foot level not less than ten million tons of ledge-matter. If this was, before alteration, a sulphide-ore of the average composition of the existing unaltered masses, there must have been set free at least four million tons of sulphur. That the ore be-

fore alteration was as compact, and therefore carried as high a percentage of sulphur, as the existing unaltered ore, may be doubted. It is possible that one reason why the sulphide-ores of to-day on the upper levels are only partially decayed is that they were composed of more compact pyrites than the ores which have been completely altered and are imbedded in ledge-matter. In any case, assuming that the ledge-matter and ore represent sulphuretted compounds now altered, there must have been oxidixed and rendered soluble more than a million tons of sulphur, which would be sufficient to produce widespread alterations in the adjacent limestones and hasten decay in the ore-masses themselves; to reach by diffusion the adjacent feldspathic rocks; to alter them; and to carry back some of their basic constituents and silica, to replace the dissolved elements of the limestones and ores.*

As I have already pointed out, the limestones themselves which enclose the ledge-matter are extensively altered. As the result of such alteration, there must have been produced correspondingly large quantities of sulphate of lime. Through the percolation of water this has been completely dissolved and removed. In dryer mines, such as those at Globe, small quantities of gypsum are found; and in such extremely dry regions as that in which the Boleo mines of Lower California are situated, gypsum accompanies the oxidized copper-ores in such quantities as to convert the furnace-product very largely into matte. At Bisbee, however, where the ledge-matter is everywhere wet, where fissures and caves afford channels for the flow of water, and where, during the wet season, our pumps have to handle from one to two million gallons of water a day, even such sparingly soluble products of decay as gypsum have been dissolved and have disappeared.

It is more difficult to account for the enormous quantities of alumina which must have been derived from extraneous sources to form the clays. They must have been derived and conveyed by diffusion from the adjacent feldspathic rocks. As I have already remarked, when we drift from the limestones into the feldspathic rocks, assumed to be rhyolite, to the east, it is impos-

* There are, within the limestone area, calcareous shales, which are probably the products of alteration, as they differ less in composition than in structure from the clays.

sible to distinguish the difference between altered limestone and altered rhyolite. But in the distinctly feldspathic rocks we find that widespread decay, though less destructive, has occurred. As this rhyolite carries more or less iron- and copper-pyrites, it may be argued that the enclosed pyrites is the effective agent in assisting decay. But except at the surface, where the rhyolite is colored, the pyrites is undecomposed. Below the surface the rhyolite is white and softened to considerable depth. It is therefore quite conceivable that, by means of the insensible interchange of solutions from the decaying bodies of pyrites through the adjacent feldspathic rocks, alumina and a certain amount of silica should be dissolved, and that they, in their turn, should displace the carbonate of lime and replace some of the iron in the altered pyrites.

At the Copper Basin in Yavapai county, Arizona, a copper-solution oozes from feldspathic rocks which carry only a trace of copper. On exposure to the air, there separates in the bottom of the streams an insoluble magma, the solid constituents of which are:

	Per Cent.
Silica,	7.17
Fe_2O_3 and Al_2O_3,	16.21
CuO,	64.40
SO_3,	12.22
	100.00

In time this sludge is converted into a mixed carbonate of copper and alumina, which binds together the gravels into conglomerates, of which some twenty thousand tons constitute horizontal beds of copper-ore. The alumina and silica are in this case dissolved from the granite, through which percolate the soluble products of the decay of copper- and iron-pyrites.

A feature of the Bisbee mine is the large caves, which have had some influence on the occurrence of the oxidized ore-bodies. The walls, roofs and floors of these caves are always covered with stalactitic accretions, which are often tinted green, blue and red by the copper- and iron-solutions which are mixed with a solution of carbonate of lime. What, however, gives these caverns practical interest is that they have invariably covered oxidized ore-bodies. Fig. 14 gives a cross-section through one of the large caves. Three such caves of considerable

extent have been encountered, and in every instance this combination has occurred. It may be accidental; but so satisfied are we to the contrary that, when a cave is now met with, drifts are run beneath it to strike the ore-body. It is a fair assumption that the cave, if not originally formed by the contraction of an ore-body, was increased by the shrinkage of the latter during its oxidation, and that, therefore, a genetic relation really exists between the cave and the underlying ore.

Moreover, some real, and not accidental, relation can be traced between the surface-contour of the country and the underlying ore-bodies.* Where the ore-bodies have come to the surface, and have been decayed into ledge-matter, erosion has been extensive, as in the case of the depression east of the Copper Queen hill, through which the Arizona and Southeastern R. R. enters the town, and in which the slag-dump shown in Fig. 7 is being made. This depression, as already observed, marks the line of contact between the limestones and the rhyolite. The fissure between the Copper Queen hill and the Copper King hill to the west uncovers the deposit of cerussite which first attracted attention to the district; and this gulch may occupy the position of ore-bodies which, there is reason to think, have been completely removed by denudation. South of the Copper Queen hill there is a broad depression, which corresponds roughly to the ore-bearing ground in depth. It would be drawing an unwarrantable conclusion to predict the position of an ore-body from the surface-contour of any country; but where the rocks are known to be ore-bearing, it is often as fair an assumption that surface elevations and depressions represent ore-bodies in depth as that the colors of soils and rocks are indicative signs.

The metallurgical practice has necessarily undergone radical modifications with the change in the character of the ore; and

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* The tremendous erosive action of water is illustrated by Fig. 2. The picture was taken when a flood, caused by a heavy shower which fell on the mountains to the rear of the town, was rushing down the main street, as well as filling the bed of the stream (always dry, except during flood). Formerly these floods were very rare; but since the timber has been cut off the range, and its scanty grass has been torn up by the roots, there is nothing to impede the rush of water, carrying with it sand, gravel and rocks.

Within a few minutes after a black cloud floats up the gulch over the town these destructive torrents tear down the valley, washing all before them.

the plant also has grown, both in size and in the dimension of its separate parts, with the expansion of the mine. The water-jacketed furnace which was introduced when the mine was opened by Mr. Lewis Williams, who was probably the first metallurgist to apply it to [illegible] has remained the type of furnace used; but the 36-inch round shell has, by successive changes, developed into furnaces of 120 inches by 42 inches. There is no other reason for confining them to this size than that the capacity of such a furnace is approximately that of the converters, which are coupled with the furnaces. Originally the furnace-plant, consisting of two 36-inch jackets, was built directly below the open-cut, and the ore was crushed under a separate roof, thus involving unnecessary handling; but in 1886–1887 the smelting-works were removed to their present site, though they were still planned for the treatment exclusively of oxidized ores. Already, however, the percentage of sulphur in the oxidized ores was increasing to a degree which injured the quality of the black-copper bars, and involved the retreatment of part of the product as matte. Simultaneously, large bodies of compact sulphurets were being discovered, the utilization of which involved a change of treatment. By that time the pneumatic method of concentrating matte had acquired such undisputed acceptance in Butte that the company decided to adopt it; but, instead of building the vertical converter, which had heretofore been exclusively used in this country, the horizontal barrel-type was copied, with modifications, from those in use at the metallurgical works in Leghorn, Italy, at Aiguilles, France, and at Vivians' works in Swansea, Wales.

At first the converters were fed from a remelting furnace; but this wasteful operation was soon abandoned, and each of the three converters was placed opposite its companion smelting-furnace, and the molten matte was poured from tilting-wells directly into the converters. Fig. 15 shows a tilting-well, from which matte is being poured into one of the converters, situated on a lower level, as shown in Fig. 16. This plan secured notable economy over the cost of remelting, with its attendant handling of the cooled matte, but was found to involve occasional delay—at one time of the furnaces, at another of the converters—so that neither furnaces nor converters could be

pushed to their maximum capacity. An electric crane is therefore being introduced to transport the matte from any one of the furnace-wells to any one of the converters. The smelting-plant of the mine will hereafter consist of four water jacketed cupolas, 42 inches by 120 inches, of oval shape, and with taper from the feed-door to the tuyeres. Each furnace is provided with two tilting-wells, arranged in tandem. From the second well the slag will flow into 2-ton ladles, which are moved by the electric crane to the 4-ton slag-cars, drawn by a steam locomotive. The matte will be poured from whichever of the tilting-wells of each furnace is quite full, and conveyed to a converter; and the same crane will return the converter-slag to the well nearest to the furnace, thus allowing the slag ample time and space to settle while travelling to the discharge of the second well. The converters are 8 feet long and 5 feet 6 inches in diameter. The average daily capacity of each furnace is about 160 tons of ore, exclusive of extra charge of foul slag, and each converter can blow daily 30 to 40 tons of 45 per cent. matte to metallic copper, averaging a trifle over 99 per cent. The blast is derived either from a horizontal duplex Riedler engine or a vertical Scranton engine. The pressure usually maintained is from 7 to 8 pounds. While the matte can be blown at much lower pressure, a lower blast retards the operation.

In *Mineral Resources of the United States* for 1883–1884, I described the construction and operation of the old 36-inch jackets then treating the oxidized ores of the mine.

At present a charge of the large 42- by 120-inch furnace is composed of naturally oxidized ores mixed with sulphuretted ores in such proportion as to yield a matte of about 45 per cent. The following samples of ore-charge and slag were taken during a day's run of the same furnace.

Each ore-charge consisted of:

	Pounds.
Oxidized ores from various parts of the mine, carrying more or less sulphur,	1,500
Low-grade clay-ore,	1,000
Raw sulphide-ore,	1,000
Roasted sulphide-ore,	100
Total,	3,600

One charge of briquettes, made from fine ore-screenings, flue-dust and coke-dust, in a Chisholm & Boyd press, is fed for every 10 charges of ore. The coarse screenings from the converter are added as extras. The larger proportion of silica and alumina in the slag than the composition of the ore-charge would warrant, comes from these screenings, and from the ash of the coke.

Analysis of Ore-Charge.

	Per cent.
Copper,	9.1
Silica,	17.1
Lime,	Trace
Sulphur,	16.44
Iron,	29.7
Aluminum,	5.4
Zinc,	Trace
Lead,	Trace
Manganese,	0.58
Moisture in the ore,	9.2
	Oz. per ton.
Silver,	0.9
Gold,	Trace

Analysis of Resulting Slag.

	Per cent.
Copper,	0.6
Silica,	33.8
Lime,	1.11
Sulphur,	1.1
Iron,	37.7
Aluminum,	13.15
Zinc,	*Nil.*
Lead,	*Nil.*
Manganese,	1.95
Silver,	Trace
Gold,	*Nil.*

The copper-content of the wet ore, as fed into the furnace, was therefore 8.27 per cent. This, of course, represents not the average run of the mine, but selected ore; as rough-sorting is done underground. No flux is ever added to the furnace-charge, as by a judicious selection of acid and basic ores a fusible mixture can always be obtained. The coke-consumption is 12.5 per cent. of burden of furnace. The coke used is a very impure product of the Trinidad, Colo., ovens, carrying over 20 per cent. of ash; but the furnace-charge is sufficiently basic to permit its economical use.

The operation of one of the converters when fed from a single furnace, involving, as already stated, a considerable waste of time, can be followed by tracing the steps of the life of a single lining, as in the following table; and the behavior of the principal ingredients of the matte is indicated by the analysis and the products of the blow.

Samples of Products of Bessemer Converter No. 3, at Bisbee, During the Life of One Lining.

NEW LINING: FIRST CHARGE.

First tap of matte from well No. 3. Blast turned on at 12.13 P.M.; blast turned off at 12.28 P.M. Time of first blast, 15 minutes. Pour finished at 12.33 P.M.	*Sample No.* 1.—First tap of matte into converter; ladle at beginning, middle and end of tap. *Sample No.* 2.*—First pour of slag, 4½ pots; dip-sample, two rods to each pot. *Sample No.* 3.—Ladle-sample of white metal from converter.
Second blow began at 12.52 P.M.; second blow ended at 1.20 P.M. Time of blow, 28 minutes.	*Sample No.* 4.—Second tap of matte into converter from well No. 3.
Third blow began at 1.30 P.M.; third blow ended at 1.58 P.M. Time of blow, 28 minutes. Bullion all poured at 2.06 P.M.	*Sample No.* 5.—Six pots, poured slag. *Sample No.* 6.—Two pots, skimmed slag. *Sample No.* 7.—White metal from converter.
Length of blast on charge: first blow, 15 minutes; second blow, 28 minutes; third blow, 28 minutes. Total, 1 hour 11 minutes.	*Sample No.* 8.—Metallic copper; ladle-sample taken near beginning and end of pour. Copper made from this charge, 9½ bars.

SECOND CHARGE OF CONVERTER.

First tap of matte from No. 3 well into converter. First blow began at 2.20 P.M.; first blow ended at 2.48 P.M. Time of blow, 28 minutes.	*Sample No.* 9.—First tap of matte taken as for sample No. 1. *Sample No.* 10.—First pour of slag, 10 pots. *Sample No.* 11.—White metal in converter, end of first blow. *Sample No.* 12.—Second tap of matte from well No. 3 into converter.
Second blow began at 3.12 P.M.; second blow ended at 3.37 P.M. Time of blow, 25 minutes.	*Sample No.* 13.—Second pouring of slag, 9 pots. *Sample No.* 14.—Two pots skimmings. *Sample No.* 15.—White metal, end of second blow.

* Sample No. 2 probably too high, as dip of rods from last pot was too deep.

Third blow began at 3.50 P.M.; third blow ended at 4.32 P.M. Time of blow, 42 minutes.

Length of blast on charge: first blow, 28 minutes; second blow, 25 minutes; third blow, 42 minutes. Total, 1 hour 35 minutes.

Sample No 16.—Taken like sample No. 8; 14½ bars of metallic copper.

NOTE.—Converter-lining patched with one wheelbarrow-load of lining after this run.

THIRD CHARGE OF CONVERTER.

First blow began at 5.10 P.M.; first blow ended at 5.41 P.M. Time of blow, 31 minutes.

Sample No. 17.—First tap of matte from settler No. 3, taken like sample No. 1.

Sample No. 18.—First pour of slag, 10 pots.

Sample No. 19.—White metal, after first blow.

Sample No. 20—Second charge of matte from No. 3 well into converter.

Second blow began at 6.10 P.M.; second blow ended at 6.35 P.M. Time of blow, 25 minutes.

Sample No. 21.—Nine pots slag, second pour.

Sample No. 22.—Two pots skimmings.

Sample No. 23.—White metal, after second blow.

Third blow began at 6.45 P.M.; third blow ended at 7.26 P.M. Time of blow, 41 minutes.

Sample No. 24.—Metallic copper, 14½ bars, taken like No. 8.

Length of blast on charge: first blow, 31 minutes; second blow, 25 minutes; third blow, 41 minutes. Total, 1 hour 37 minutes.

NOTE.—Converter-lining reinforced with one wheelbarrow-load of lining after the run.

FOURTH AND LAST CHARGE OF CONVERTER.

NOTE.—Had to wait nearly an hour for matte, as No. 3 furnace had been run down.

First blow began at 8.43 P.M.; first blow ended at 9.09 P.M. Time of blow, 26 minutes.

Sample No. 25.—Matte (only tap) poured from No. 3 well.

Sample No. 26.—Nine pots slag poured.

Sample No. 27.—One pot of skimmings.

Sample No. 28.—White metal in converter after first blow.

Second blow began at 9.19 P.M.; second blow ended at 9.56 P.M. Time of blow, 37 minutes.

Sample No. 29.—Metallic copper, 12 bars.

Sample No. 30.—"Granulated slag," 2 pots grab as raked out.

Sample No. 31.

Sample No. 32.

Total time of blast: first blow, 26 minutes; second blow, 37 minutes. Total, 63 minutes.

Product, 52 bars; weight, 15,070 pounds.

NOTE.—In blowing up the charges to white metal, there were always some fumes coming from the converter. But the fumes were very much heavier than usual in the last charge. In fact there were very dense fumes, probably lead, through almost all of the time of the first blow on the fourth charge.

Assays of Above Samples.

FIRST CHARGE.

	Matte. No. 1.	Slag. No. 2.	White Metal. No. 3.	Matte. No. 4.	Slag. No. 5.	Slag Skimmings. No. 6.	White Metal. No. 7.	Copper. No. 8.
	Percent	Percent.	Percent.	Percent	Percent.	Percent.	Percent.	Percent.
Silica	....	36.78	....	....	34.04	36.62	....	....
Copper	55.48	3.09	78.79	55.40	4.36	6.84	79.22	98.64
Iron	21.09	45.82	0.86	21.06	48.47	43.01	0.47	0.159
Nickel	0.34	0.28	0.07	0.26	0.56	0.38	0.15	0.04
Zinc	0.16	....	0.04	0.09	....	....	0.06	0.027
Lead	0.612	....	0.12	1.04	....	....	0.13	0.034
Antimony	0.021	....	0.010	0.031	....	....	0.014	0.009
Arsenic	0.051	....	0.014	0.032	....	....	0.015	0.012
Selenium and Tellurium	0.05	....	0.015	0.029	....	....	0.043	0.043
Sulphur	21.39	0.26	19.78	21.93	....	....	19.45	0.244
Silver*	(9.02)	(0.20)	(9.12)	(6.82)	....	....	(10.22)	(12.24)
Gold*	(0.12)	....	(0.20)	(0.10)	....	....	(0.22)	(0.24)
Insol. resid	0.34	....	....	....	....	....	....	0.196

SECOND CHARGE.

	Matte. No. 9.	Slag. No. 10.	White Metal. No. 11.	Matte. No. 12.	Slag Poured. No. 13.	Slag Skimmings. No. 14.	White Metal. No. 15.	Copper. No. 16.
	Percent.	Percent.	Percent.	Percent.	Per cent.	Per cent.	Per cent.	Per cent.
Silica	....	35.30	....	....	33.46	39.62	....	....
Copper	54.04	4.08	79.10	50.50	4.47	4.31	78.44	98.90
Iron	21.35	47.05	0.595	24.95	49.60	42.44	0.86	0.184
Nickel	0.24	0.39	0.072	0.22	0.96	0.49	0.15	0.033
Zinc	0.145	....	0.031	0.08	....	....	0.063	0.004
Lead	1.21	....	0.192	2.12	....	....	0.37	0.103
Antimony	0.02	....	0.006	0.033	....	....	0.013	0.014
Arsenic	0.04	....	0.015	0.035	....	....	0.016	0.016
Selenium and Tellurium	0.04	....	0.022	0.035	....	....	0.042	0.045
Sulphur	21.67	....	19.46	21.61	....	....	19.59	0.403
Silver*	(6.08)	(0.18)	(10.64)	(6.08)	....	....	(9.28)	(11.13)
Gold*	(0.16)	....	(0.18)	(0.12)	....	....	(0.20)	(0.25)
Insol. resid	0.51	....	....	....	....	....	....	....

* The figures for silver and gold, in parenthesis, represent ounces per ton. As 9.02 ounces is much more silver than any of our low-grade melts contain, this sample is undoubtedly incorrect; and therefore the silver and gold in the second sample (next table) should be taken for purposes of comparison.

THIRD CHARGE.

	Matte. No. 17.	Slag. No. 18.	White Metal. No. 19.	Matte. No. 20.	Slag Poured. No. 21.	Slag Skimmings. No. 22.	White Metal. No. 23.	Copper. No. 24.
	Percent.	Percent.	Percent.	Percent.	Percent.	Percent.	Percent.	Percent.
Silica	....	34.35	....	....	32.60	37.84	....	....
Copper	53.46	2.87	78.98	55.30	4.12	4.94	78.92	98.02
Iron	21.95	48.40	1.10	19.99	54.33	43.10	0.86	0.161
Nickel	0.24	0.76	0.07	0.29	0.99	2.02	0.12	0.042
Zinc	0.18	0.39	0.03	0.09	....	....	0.06	0.016
Lead	1.89	1.51	0.10	1.37	....	....	0.26	0.11
Antimony	0.03	....	0.005	0.03	....	....	0.014	0.02
Arsenic	0.05	....	0.014	0.04	....	....	0.015	0.016
[illegible]	0.04	....	0.018	0.03	....	....	0.026	0.048
Sulphur	21.72	....	19.32	22.49	....	....	19.47	0.51
Silver*	(6.76)	(0.11)	(9.80)	(6.40)	....	....	(8.88)	(11.86)
Gold*	(0.14)	....	(0.20)	(0.12)	....	....	(0.18)	(0.24)

FOURTH CHARGE.

	Matte. No. 25.	Slag Poured. No. 26.	Slag [illegible] No. [illegible]	[illegible]	[illegible]
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Silica	....	32.57	35.16	....	....
Copper	57.86	3.18	4.22	77.58	99.05
Iron	17.68	50.84	50.48	0.93	0.164
Nickel {	0.12	....	....	....	....
	0.33	0.19	1.84	[illegible]	[illegible]
Zinc	0.21	0.42	....	0.05	0.016
Lead	1.85	2.25	....	0.48	0.08
Antimony	0.03	....	....	0.15	0.018
Arsenic	0.04	....	....	0.17	0.016
Selenium and Tellurium	0.04	....	....	0.02	0.044
Sulphur	21.34	....	....	20.11	0.07
Silver*	(5.86)	(0.16)	....	(7.86)	(12.73)
[illegible]	(0.12)	....	....	(0.18)	(0.27)
[illegible]	0.39	....	....	....	....

	Granul. Slag Rakings. No. 30.	Hood. No. 31.	Lining. No. 32.
	Per cent.	Per cent.	Per cent.
Silica	43.14	1.14	86.64
Copper	9.27	75.72	0.23
Iron	27.195	3.31	2.22
Nickel	0.912	0.26	....
Aluminum	....	0.22	3.71
Zinc	0.04	0.168	....
Lead	2.84	1.51	....
Antimony	....	0.028	....
[illegible]	....	0.033	....
[illegible] Tellurium	....	0.053	....
Sulphur	....	12.40	....
Silver*	(0.52)	(7.50)	....
Gold*	....	(0.10)	....

* The figures for silver and gold, in parenthesis, represent ounces per ton.

In summary: 9 h. 43 min. were consumed in making 15,070 pounds of copper, in four charges, or 2 h. 25 min. per charge. To this, 20 min. must be added for the time allowed for changing converter-shells.

The first charge was blown up to copper in 1 h. 11 min.; the second, in 1 h. 35 min.; the third, in 1 h. 37 min.; and the fourth, in 63 min. Total, 5 h. 26 min.

The skimming and second matte-filling actually occupied 34 min. for the first charge; 37 min. for the second; 39 min. for the third; and the skimming of the fourth charge occupied 16 min. Total, 2 h. 6 min.

The difference of 2 h. 11 min., or 33 min. per charge, between the total of 9 h. 43 min. and the 7 h. 32 min. taken in blowing, skimming and matte-filling, was therefore spent in pouring copper, patching and charging,—an excessive allowance, due in part, as previously explained, to the system, otherwise so economical, of linking a furnace to one converter.

The converter-lining used in Bisbee is composed of quartzite and clay from the mine, the latter carrying a small percentage of copper. No ore sufficiently siliceous, and, at the same time, sufficiently plastic, has been found at Bisbee to serve as lining; but at Morenci an ore with an average composition of 54 per cent. SiO_2 and 20 per cent. Al_2O_3 is used to line the body of the converter. A more siliceous mixture is preferred for the zone of the tuyeres. The small quantity of gold and silver, which the above analyses reveal, comes from every section of the mine—a certain stope containing more on one day than on another day. For a time a selection was made, one converter and one furnace being run on the more highly argentiferous ore, and bars of slightly higher tenor in gold and silver were made from them; but the difference between these and the average was too small to encourage us in continuing the practice. No roasting is actually needed; but two cylinder calcining-furnaces are kept running on very heavily sulphuretted ores, extracted chiefly during exploration. The furnaces are automatic and self-roasting. Each handles 8 tons of coarsely crushed ore a day, reducing the average sulphur contents from 45 to 8 per cent.

The power-plant of the works, like that of all plants built up

by instalments, is very defective. No steps are being taken to improve it, because the company contemplates building, in the near future, a large gas-producer and gas-engine plant, the experience of both the Arizona Copper Co. and the Detroit Copper Mining Co. having been overwhelmingly and unreservedly favorable to that mode of generating power, at least under the local conditions here existing.

Natural Coke of the Santa Clara Coal-Field, Sonora, Mexico.

BY E. T. DUMBLE, HOUSTON, TEXAS.

(California Meeting, September, 1899.)

DURING explorations made for the Pacific Improvement Company in the early part of this year, deposits of natural coke, of such extent and excellent quality as to be worthy of record, were found in the Santa Clara coal-field. This coal-field lies in the neighborhood of La Barranca, a small town, 95 miles northeast of Ortiz, on the Sonora railway. The coal-beds are exposed in the drainage-basin of Calera creek, which empties into the Yaqui river opposite Toniche; and the old mining town of Tarahumari is nearly at the center of the field.

Without going into a detailed geological description, it will be sufficient to say that the entire area is underlain by rocks of Triassic age, much disturbed in places, and cut through and covered by eruptive rocks of various kinds and ages. The coal-beds occur in a series of interbedded sands and clays, in the upper half of the sedimentary Triassic rocks. Below them is a great series of quartzitic sandstones and very sandy slates, and above them are other sandstones, and the eruptive member of the group, viz., the Lista Blanca formation, described in my paper on the "Geology of Sonora," presented at the New York Meeting of February, 1899.*

Speaking very broadly, these sands and clays, with their included coal-beds, dip about 30 degrees S.E. This gives their outcropping edges a N.E.–S.W. direction. The general dip

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* *Trans.*, xxix., 122.

and strike are, however, often changed by the bodies of eruptive rock which have intruded themselves between certain beds, so that the dip may be anything from south to east, with even northerly dips in a few localities. The angle varies from 15 degrees, or less, to 60 degrees or a little more; but these extremes are rare, and obtain for limited areas only. The beds have been somewhat folded, the general axes of the folds being nearly north and south. In a few instances these folds run out into faults; but, as a rule, the faults have only a very moderate throw.

The rocks of the coal-measures are sands and clays. These have been altered, in most instances, into hard sandstones and quartzites on the one side, and into slates on the other. Trachyte, diorite and phonolite are the principal eruptive rocks present.

The slates and sands vary from pure clay-slates, through sandy clays, clayey sands and sandy slates, to sandstones; and these variations may be observed in the same bed, if it be traced a sufficient distance, either horizontally or vertically. Only a few beds are persistent through considerable distances as distinct sands or clays. The strata are for the most part quite evenly bedded; cross-bedding having been observed to a very small extent only.

The eruptive rocks have been forced in between the other materials; and, although in places they do cut across the strata, they occur in the coal-area principally along bedding-planes. This gives them the appearance of being interbedded with the sandstones and slates, and so closely do they simulate one or the other of these in outside appearance that they may often be overlooked until, at some point, they suddenly increase in thickness from 1 to 20, 30 or more feet, forming laccolites, and throwing the overlying rocks out of their regular trend. It is to such laccolites that the principal flexures of the beds are due.

The largest laccolite observed is the great body of diorite west of Tarahumari. Its length from north to south is half a mile, and its width is not much less. It has come in between the Tarahumari sandstone and the [illegible] slate, and, in places, has even intruded into the slates, so that it now appears to be interbedded with them as well as to overlie them. This is the only diorite laccolite observed; the others are nearly all

trachytic. These interbedded lavas have had much to do with the alteration into coke of that part of the coal with which they have come in contact.

In our search for coal-outcrops on Calera creek we came across a fragment of coke, and, tracing it up, finally found a small bed of impure coke at the mouth of El Tren, one of the principal tributaries of that stream. A few days later, one of the prospect-slopes, driven on a supposed coal-outcrop, opened out into a body of 3 feet of good coke, underlain by 2 feet of anthracite.

Later still, as we were prospecting a creek somewhat over half a mile west of the last, we found a place where the gophers had brought out some coal-dust, and put men to work on it. Within 10 feet it opened into a good body of coke, which at 30 feet depth was 8 feet thick and at 130 feet depth was over 10 feet thick.

Besides these two principal openings, which we subsequently proved to be in the same bed, we have since located several other deposits, with thicknesses of from 2 to 4 feet.

In almost every instance there is a close relation between the intrusive rock and the coke. In the two principal openings, the igneous rock either forms the roof or is separated from the coke by a very thin band of slate; and in both slopes there are places where the coke holds included blocks or stringers of the intrusive rock. In another opening the igneous rock forms the floor; and here, too, it is occasionally mingled with the coke; while, in still another, the very plastic nature of the igneous rock at the time of its intrusion is shown by the fact that it fills even small crevices in the coke along the line of contact.

It is possible, however, that the coke is not entirely due to the effect of the igneous rock. One bed of coke has, so far as we have found, no igneous rock near it; and again, at one locality, there are small pockets of coke in a 4-foot seam of anthracite, and, so far, we have not found any intrusive rock in the immediate vicinity. These pockets are at about the center of the seam, and are small; but the coke is of good quality. Corresponding in a way to the occurrence of the coke in the anthracite, we find, for the first 50 or 60 feet, in the Gopher slope, a little anthracite in pockets at the base of the coke.

The occurrence of coal and coke in the same bed, but in separate benches, is also noticeable. This is found in three separate localities, and in different beds. In two cases the coke forms the upper bench, and in the other the coal is on top. In the first opening mentioned above, the two benches are separated by a clay parting, 3 inches thick. In the other two I did not find any parting.

Where the coal is crushed, a little graphite is found along the lines of fracture. I have not found it elsewhere in the beds. Some of the anthracite of the region also has a little graphite, in similar relation; and there are several localities where the entire bed is altered to graphite. The occurrence in the coke-seam is interesting, however, as it shows that in the cumulative transformation from vegetable fiber to graphite, the passage may be either through anthracite or through natural coke.

The coke is dark gray in color, of even texture, with small pores (denser than most oven-coke), and very firm. It breaks with very even fracture, but has in places the columnar structure of oven-coke well developed.

It is an excellent fuel, burning without any sparking or deflagration. It is little or no harder to ignite than the anthracite, and burns well in an open fire, in the blacksmith-forge and in the assay-furnace. The ash is white.

The value of these coke-beds is largely due to the fact that the intrusives are so regularly interbedded, running for long distances in the same bed of coal-slates. This gives promise of a far greater supply of coke than could be hoped for under other conditions, and gives to the deposit, in this region, where there is no coking-coal of any kind, a decided commercial importance.

Notes on the Life of Steel Wire Cables.

BY PROF. FRANK SOULÉ, UNIVERSITY OF CALIFORNIA, BERKELEY, CAL.

(California Meeting, September, 1899.)

SECRETARY E. H. Benjamin, of the California Miners' Association, has proposed and begun, in co-operation with the testing laboratory of the University of California, at Berkeley, a series of tests which should prove of great interest and practical use to all persons making extensive application of steel wire cables, and especially to miners who run them in deep mines. Mr. Benjamin is endeavoring to obtain pieces of cable both new, and old and worn, from every deep mine of importance on the Pacific Coast, together with all the data obtainable concerning their manufacture and particular use. Pieces from each sample will be broken in the laboratory before mentioned; and as far as possible the effects of winding around drums or pulleys; of sudden starting and stopping when loaded; of heavy shocks, and of the general wear and tear of the cables, will be ascertained by these tests. The Olsen testing-machine of 200,000 pounds capacity will be used to break the cables, and the rupturing force, in different instances, will be applied slowly and also rapidly, in order to make the tests comparable as far as possible with the practical use of the cables themselves. All information and data available should be obtained for each specimen sent to the laboratory, the name of the manufacturer, the date of making, strength of cable when new and unrusted, as well as the circumstances and conditions of the practical use of the cable. Having this information before us, we shall be able to tell, approximately at least, the effects of age, rust, wear and tear, shocks, etc.; and perhaps be enabled to draw the line of limitation beyond which it would be no longer safe to use a cable of known manufacture.

Moreover, by means of such tests we may, perhaps, be able to recommend worn cables for other uses, less severe in character, thereby prolonging the life of their effective usefulness.

When we consider the great number of miles of steel cable now in use, and of the greater number constantly being manu-

factured, we can see that the satisfactory answers to our questions will be of great importance to miners, as well as to engineers generally. In order to make the record complete, and the results satisfactory and reliable, the fullest data should in every case accompany the samples of cables sent to be tested. Unfortunately, thus far there have been few cases in which the data given were considered ample and complete. But from the small number of tests already made we may, perhaps, be justified in drawing a few general conclusions; namely, (1) that the effect of ordinary rust on the strength of steel wire cables is not as great as has commonly been supposed, and that the rusting may be almost entirely prevented by carefully coating with tar, etc.; (2) that the weakening effect of bending the cable around a drum, of large size compared with the diameter of one cable, is almost nothing; (3) that the cable which exhibits a great deal of wear on its exterior surface, and is apparently much diminished in strength, is not nearly as much weakened as is commonly supposed, and retains a large percentage of its original strength, particularly when stressed by gradually increasing loads, applied without shock.

These conclusions are no more than provisional, having been drawn from a small number only of tests, and may be greatly modified in the final report.

A full account of the samples, tests and conclusions finally drawn therefrom will be published by the American Institute of Mining Engineers; and also as a bulletin of the University of California.

The latter will be distributed through the medium of the California Miners' Association to all persons who are interested in the subject.

The data particularly desired are:

1. A descriptive number on the sample.
2. The size of the cable when new, and the material.
3. The name of the manufacturer, and the date of making.
4. The strength when new, as tested, with the circumstances of the test.
5. The time when first used.
6. The length of cable in use, or under stress.
7. The conditions and circumstances of use of each sample.
8. Diameter of sheave.
9. Diameter of drum.

10. Speed of hoisting, *i.e.*, feet per minute.
11. Speed of lowering.
12. Angle of shaft.
13. Number of daily trips.
14. Weight of load on sample cable.
15. The lubricant used.
16. Circumstances as to sudden loads, shocks, etc.

Physical Tests of Some Pacific Coast Timbers.

BY PROF. FRANK SOULÉ, UNIVERSITY OF CALIFORNIA, BERKELEY, CAL.

(California Meeting, September, 1899.)

Our Pacific Coast region is peculiarly lacking in "hard-wood" or "deciduous trees," which are, at the same time, suitable for timber, and numerous enough to be of commercial importance. But of the soft-wood trees, the "coniferæ," we have an abundance, the wealth of our coast in these woods being renowned the world over. In this region we have sixty species of coniferæ. In fact, nine-tenths of all the trees on the Pacific Coast are cone-bearers.

Douglas Spruce.

Most prominent among our timber-trees is the notable "Douglas spruce" (*Pseudotsuga taxifolia*), discovered by David Douglas, of Scotland, in 1825, on the Columbia river. This most useful tree is grandly imposing in appearance, widely known, and extensively applied in the constructive arts, and has, perhaps, received more names than any other tree so recently discovered. It has been called, in different times and places, *Pseudotsuga Douglasii*, *Pinus Douglasii*, *Pinus* [illegible] *Abies Douglasii;* and, in common parlance, "Douglas fir," "Douglas spruce," "yellow fir," or "red fir," according to its color; and, by lumbermen and builders, "Oregon pine," "Puget Sound pine," etc. Authorities at the present day seem inclined to center upon the designation *P*[illegible] *taxifolia*, or "Douglas spruce."

It constitutes vast forests in the Puget Sound region, as well as in Washington and Oregon. Along those coasts it grows very tall and slender, sometimes attaining a height of 400 feet; but, in the interior and in open groves, it is usually shorter and

stouter, being sometimes 10 or 12 feet in diameter at the butt. This tree is the most important and valuable, commercially, of all the northwestern conifers.

From this variety the joists, rafters, flooring, ships' planking, fencing, masts, spars, piles, bridge-timbers, mining-timbers, and other cheap, strong and durable pieces of world-wide reputation have chiefly been obtained; and through it, more than through any other tree, has fame been given to "the northwest lumber-region."

Our tests of timber from *Pseudotsuga taxifolia*, or Douglas spruce, as made in the civil engineering laboratory of the University of California, at Berkeley, prove it to be a strong and durable wood, comparing most favorably with the pines of other countries. Its resistance to tension, compression and cross-breaking is very high; its only weak points seem to be in the matter of shearing along the grain of the wood, and in splitting. In construction, therefore, as little splitting, or shearing-strain along the grain, should be brought to bear as is practicable. The long, straight fibers in this timber serve admirably, like steel wires, to resist being torn apart longitudinally, and, as columns, in compression, to resist crushing; but they seem to have comparatively little lateral adhesion, as they slip past one another, or split apart, under small stress.

All recorded tests made upon this fine timber go to prove what has all along been believed and accepted in practice, namely, that in this timber the constructor has an excellent and reliable material, which will compare most favorably with the soft woods from any part of the world. Some numerical results of tests in our laboratory are recorded below:

Oregon Pine (Pseudotsuga Douglasii, or Taxifolia).

Average specific gravity of 20 specimens,	0.592
" weight per cubic foot of 20 specimens,	36.99 lbs.
Percentage of moisture in 16 specimens,	16.35
Modulus of strength at elastic limit, 21 specimens,	6,938
" " " " rupture, 21 specimens,	9,334
" " elasticity, 21 specimens,	1,862,947
Ultimate strength—Tension, 63 specimens,	14,388
Compression, 59 specimens,	5,556
Compression across fiber, reduction in height of piece of 3 per cent., 83 specimens.	879
Compression across fiber, reduction in height of piece of 15 per cent., 83 specimens,	1,215
Longitudinal shear, 85 specimens,	546

CALIFORNIA REDWOOD.

California enjoys the distinction of being the only home of this magnificent forest tree, the *Sequoia sempervirens*. This first cousin to the *Sequoia gigantea*, and with which it may be compared in height, size and grandeur, is found only on the slopes of the Coast Range in California, from Monterey as far north as Oregon. The growth of redwood is often very dense, as many as 25,000,000 feet B. M. having been cut, in earlier times, from 160 acres of land; or at the rate of 150,000 feet B. M. per acre; and, in one instance, a single acre contained 2,500,000 feet B. M. of standing redwood, and yielded [illegible] feet of cut lumber. Of course, such quantities are exceptional, and result from an exceedingly crowded growth of very large trees over limited tracts. Such forests often contain specimens from 200 to 325 feet in height, the trunks having a diameter of from 5 to 25 feet. One of these giant redwood trunks, near Bucksport, yielded, a few years since, 480,000 feet B. M. of first-class lumber, and many other trees have yielded 400,000. The average cut for a redwood forest is not far from 40,000 feet B. M. per acre. The timber is so plentiful as to be of great commercial value, and able of itself alone to establish a "redwood market." This species is very tenacious of life, and will sprout from a damaged trunk or stump, or from the seed, under the most discouraging conditions. Given a fair chance, it quickly re-forests denuded areas.

Redwood timber is light, fairly strong, and very easy to work and shape. It resists decay well, even when buried in the soil, and is a favorite lumber throughout California for sills, fencing, railroad ties, and innumerable other constructive purposes; in fact, it is a popular, and probably the most useful, wood in California. It does not ignite and burn readily, and this property, together with its resistance to decay when underground or in damp situations, should render it useful in mines, shafts, etc. Redwood offers a soft, spongy resistance to cross-fiber compression, which gives it a comfortable, yet non-enduring, quality in railroad cross-ties, and under similar conditions. It shrinks greatly in the direction of the length of the fiber, in seasoning. These fibers are rather brittle in character, as compared with those of Douglas spruce, so that its strength in

columns and girders is very inferior to that of the latter timber. I broke, some time since, in our Olsen testing-machine, two redwood beams, which were 5 inches broad, 16 inches deep, and 18 feet between points of support. The stress was applied perpendicularly to the middle of the beam in each case. The first beam, which was very green and wet, yielded on the crushing-side at 18,400 pounds; and the second beam, which was much drier, yielded, in the same way, at 25,600 pounds.

Humboldt Redwood (Sequoia Sempervirens).

Average specific gravity of 126 pieces,	0.48
" weight per cubic foot,	29.91 lbs.
Percentage of moisture, average,	15
Modulus of strength at elastic limit, 5 specimens,	3,557
" " " " rupture, 9 specimens,	4,920
" " elasticity, 8 specimens,	797,460
Ultimate strength—Tension, 27 specimens	6,596
Compression, 29 specimens,	4,407
Compression across fiber, reduction in height of piece of 3 per cent., 30 specimens,	967
Compression across fiber, reduction in height of piece of 15 per cent., 30 specimens,	1,200
Longitudinal shear, 10 specimens,	505

Mendocino Redwood (Sequoia Sempervirens).

Average specific gravity of 3 pieces,	0.68
" weight per cubic foot of 3 pieces,	42.56 lbs.
Percentage of moisture, 6 specimens,	67
Modulus of strength at elastic limit, 1 specimen,	5,971
" " " " rupture, 7 specimens,	7,138
" " elasticity, 7 specimens,	1,143,960
Ultimate strength—Tension, 23 specimens,	9,584
Compression, 10 specimens,	4,364
" across the fiber, reduction in height of piece of 3 per cent., 24 specimens,	692
Compression across the fiber, reduction in height of piece of 15 per cent., 24 specimens,	834
Longitudinal shear, 4 specimens,	268

The Peculiar Ore-Deposit of the East Murchison United Gold-Mine, Western Australia.

BY D. P. MITCHELL, PALO ALTO, CAL.

(California Meeting, September, 1899.)

WESTERN AUSTRALIA is the home of much that is new and interesting in the gold-mining industry. Some of the gold deposits are outranked for size and value by nothing yet discovered, while the value of the ores is, in many cases, rivaled only by their complex character. As in all parts of the world, many of the ore-bodies occur in ways which tax the skill of the miner in following them; and among these the writer considers the case of the East Murchison United more interesting than the average. This is one of the leading gold-mines of the colony in point of production, and is situated near the town of Lawlers, in the East Murchison district. The country for several miles around the mine is mainly granite, and the line of outcrop on which this mine is located can be traced for a long distance. As will be seen from the accompanying plan (Fig. 1), there are, at the water-level, two nearly parallel veins running slightly north of west.

Structural Features.—The most striking peculiarity of these veins, and the hardest to understand, is their tendency to send out horizontal stringers or side-veins. These vary in size from a veinlet an inch thick to a vein several feet in width, and they extend with great persistence into the wall-rock on either side of the vein. This tendency is shown in Figs. 2 and 3.

The usual signs of a movement of the wall-rocks, such as a ribbon-structure of the quartz and a well-defined gouge or seam of clay along the walls, are in many places lacking, while in other places they appear strongly marked. They seem more in evidence below water-level than above.

It is a commonly accepted idea that when a gold-bearing vein loses in width, it often gains in value. In this instance, however, the direct opposite is the case; for in many stopes it has been possible to leave the narrow portions of the vein to act as pillars, and to extract only the wide portions, which are

of high grade. This reduces the cost of stoping, and is of advantage in many ways. Although the narrow portions of the vein proper are of low grade, it is a strange fact that the stringers, of whatever size, are usually of high grade, some of the smallest ones containing much coarse gold. Their connection with a narrow portion of the vein seems to make no difference with their capacity for carrying value.

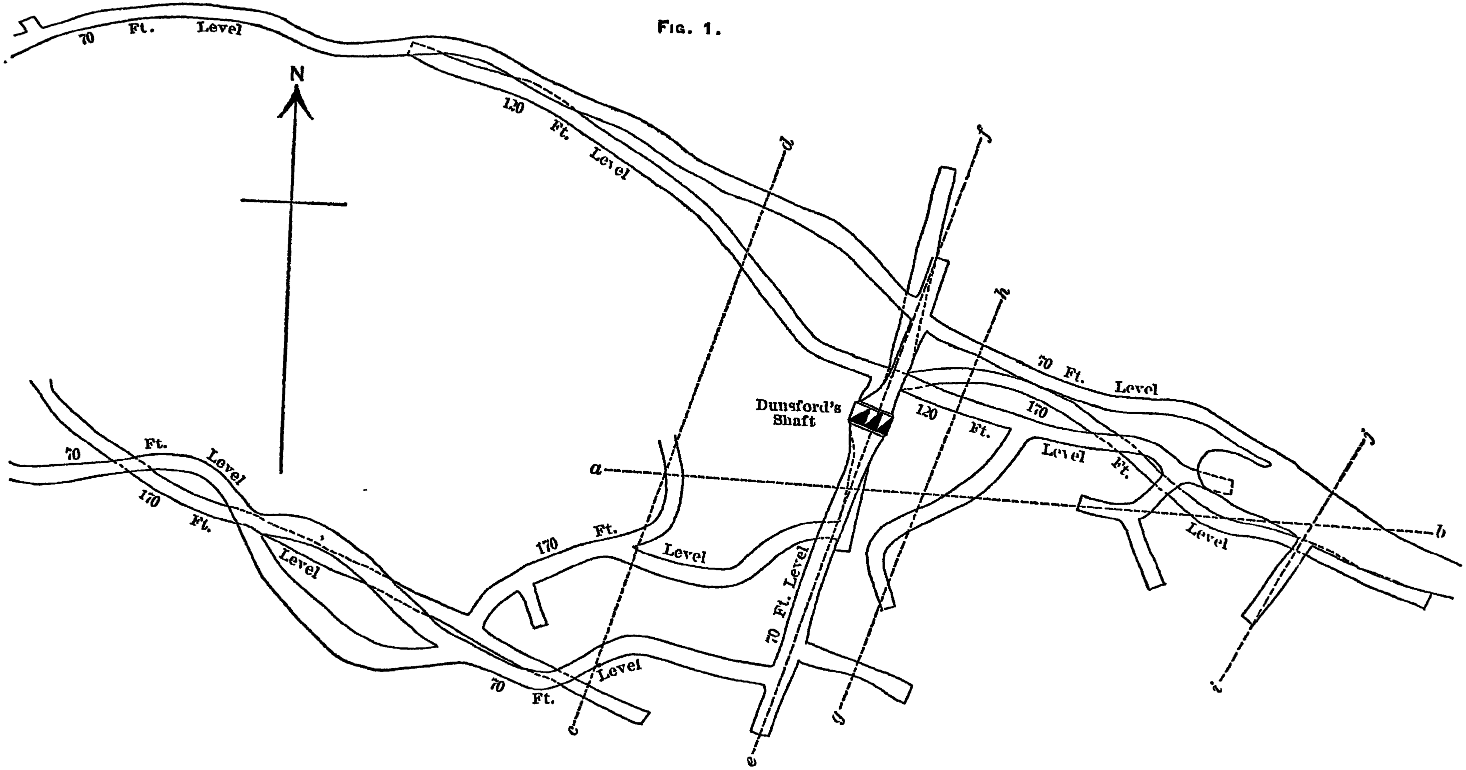
In drawings on such a small scale as those which accompany this paper, it is manifestly impossible to show the great numbers of small stringers which branch out from the main ore-bodies. It is enough to say that in places they were numerous enough to make valuable ore out of what would have been, except for their presence, worthless wall-rock. In other words, they increased the available width of the stopes by several feet.

Mineralization.—Portions of the veins are heavily charged with iron pyrites, both cubical and massive, and other portions with galena, usually in a finely disseminated condition. It is a matter worthy of notice that wherever an ore-chute is heavily charged with galena the fineness of the bullion saved by amalgamation drops from 5 to 10 per cent. below its normal grade. The whitish color of the bullion indicates plainly its decrease in value. The concentrates obtained from the ore, after removing the free gold by amalgamation, are of very high grade, running from $700 to $900 per ton.

In those portions of the veins extending from the surface nearly down to water-level, a curious phenomenon is to be observed. This consists in the secondary mineralization of the veins, taking the form of arborescent and massive occurrences of iron and manganese oxides. These are found along the cleavage-planes and in cavities throughout the veins, and are probably derived from the decomposition and solution of various minerals from the veins and wall-rocks, and their deposition in these forms. These secondary deposits, which are almost invariably very rich in gold, mark the superficial enrichment which has taken place in so many of the quartz veins of this colony.* The fact that they do not extend below water-

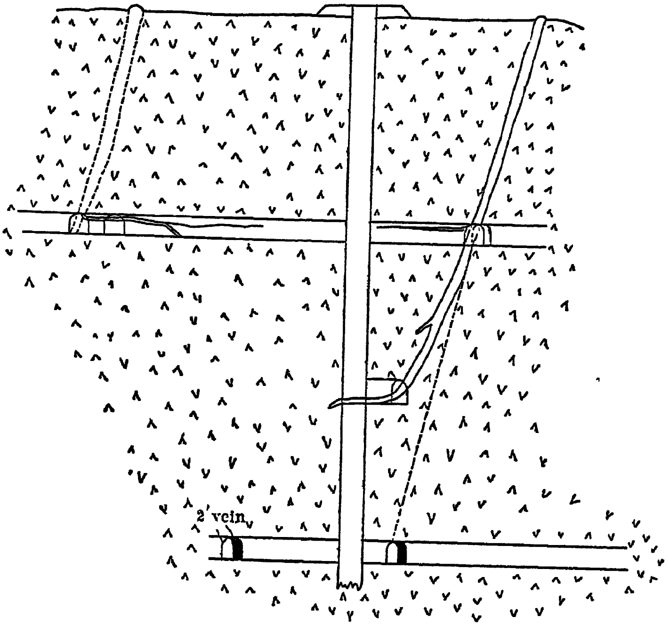
* H. C. Hoover has treated this subject at considerable length. See his paper on "The Superficial Alteration of Western Australian Ore Deposits," *Trans.* xxviii., 758 (Oct., 1898).

Fig. 1.



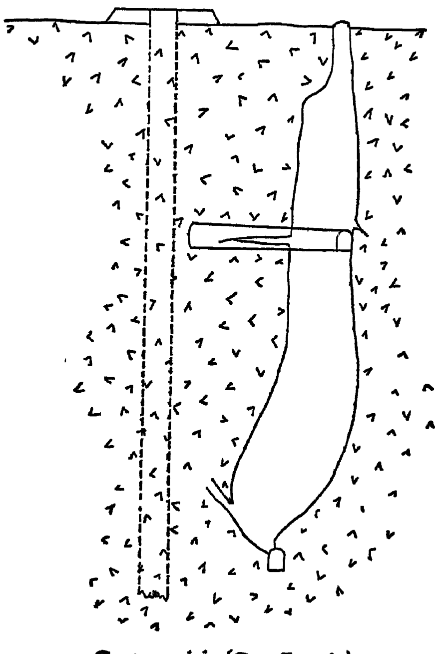
AMERICAN BANK NOTE CO., N.Y.

FIG. 2.



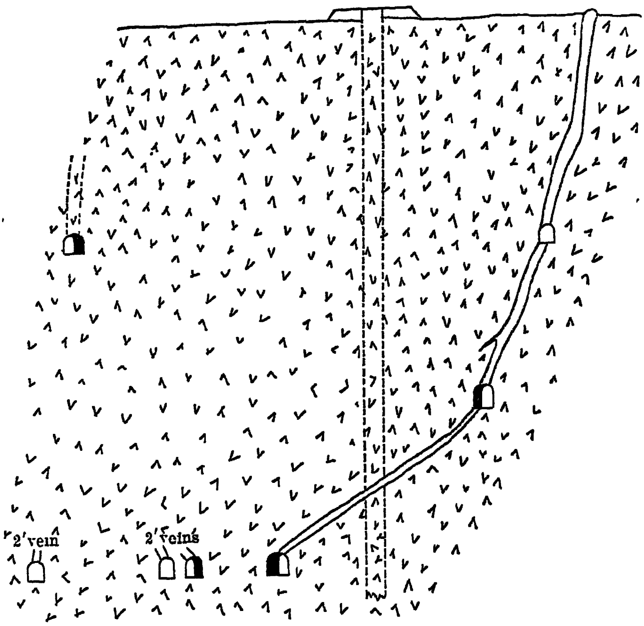
SECTION *e f*, (SEE FIG. 1.)

FIG. 3.



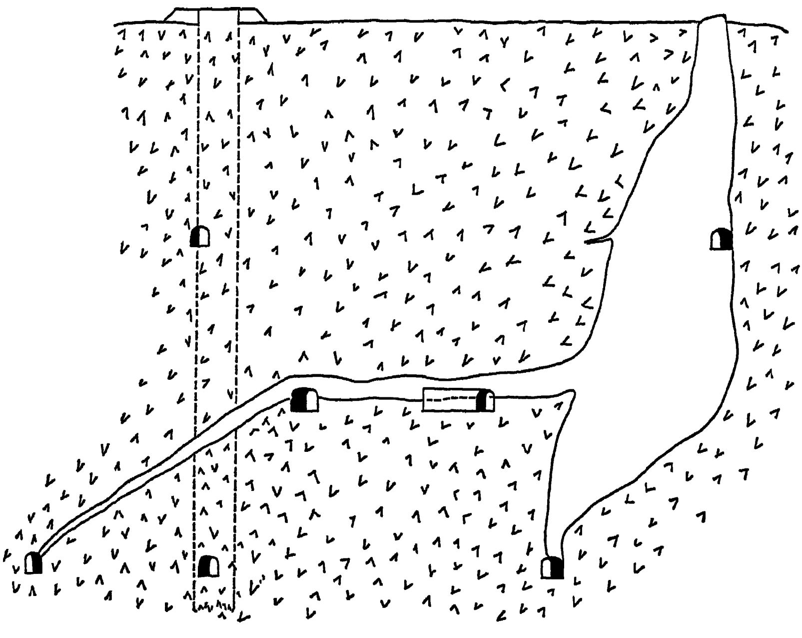
SECTION *i j*, (SEE FIG. 1.)

FIG. 4.



SECTION $c\ d$, (SEE FIG. 1.)

FIG. 5.

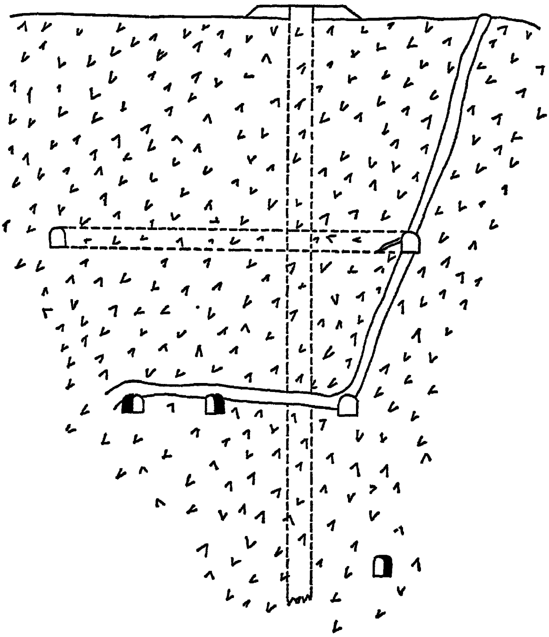


SECTION $a\ b$, (SEE FIG. 1.)

level, or into the zone of sulphide minerals, is evidence of their secondary nature.

Influence of Structure on Development.—From developments on the surface and at water-level the deposit seemed to consist of two slightly converging veins having approximately the same dip; but as greater depth was attained an intricate system of cross and horizontal fissuring was revealed. The tendency of the veins to become horizontal at times and to send out horizontal stringers was not at first regarded as of much import-

FIG. 6.



SECTION *g h*, (SEE FIG. 1.)

ance, and, consequently, development-work was planned on the supposition that the dip of the veins at water-level would continue in depth, as shown in the section through the main shaft, Fig. 2. When the full significance of the horizontal occurrences was realized, the plan was adopted of sinking winzes to find where the vein became flat, and thus indicate where to locate the levels. The 120-foot level, as shown in the plan, is located on one of these horizontal veins, and its relation to the main vein is shown by the sections *ab* and *gh*, Figs. 5 and 6. On the west 70-foot level of the southern vein is seen a good

example of a horizontal roll, one drift following the hanging- and the other the foot-wall.

The large size and high value of these horizontal portions of the veins render them very valuable additions to the ore-reserves. In extracting ore from them, the roof is supported by cribs, locally termed "pig sties," until the whole space can be solidly filled in with waste-rock.

The accompanying figures will probably need little explanation. Fig. 2 shows some small stringers extending a long distance from the vein, and Fig. 3 shows a large horizontal stringer on the 70-foot level, where its extent was revealed by a cross-cut. The plan embraces only that portion of the workings necessary to a complete understanding of the sections.

The Relative Desulphurizing Effect of Lime and Magnesia in the Iron Blast-Furnace.*

BY O. R. FOSTER, BROOKLYN, N. Y.

(California Meeting, September, 1899.)

THE use in the iron blast-furnace of slags high in magnesia has been generally condemned, not only on the ground that magnesia renders the slag less fusible, but also because it is said to have less power to remove sulphur from the iron.

Percy† says the use of dolomite as a flux should obviously be avoided, because magnesia "tends to induce infusibility," but says nothing of its relation to sulphur in the charge.

Bell‡ suggests the absorption of SO_2 by lime and magnesia in the blast-furnace, but leads the reader to suppose that the really active agent is lime.

Howe§ says:

"The greater desulphurizing power of lime than of magne-

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* The work described in this paper was done in the metallurgical laboratory of Columbia University, New York, and the paper itself is abridged from a thesis prepared in that department of the University.

† *Met. of Iron and Steel*, London, 1864, p. 506.

‡ *Chem. Phen. of Iron-Smelting*, London, pp. 263, 285.

§ *Metallurgy of Steel*, New York, 2d ed., 1891, p. 51.

sia is illustrated by the Illinois blast-furnace practice, in which the substitution of calcite for dolomite materially diminished the percentage of sulphur contained in the cast-iron."

Phillips and Bauerman say* that "magnesia . . . . has no power of absorbing sulphur."

Ledebur asserts† that the desulphurizing effect of magnesia is smaller than that of lime, magnesium having but little affinity for sulphur, but adds: "Nevertheless, a basic magnesian slag will likewise take up sulphur from the iron." He cites in this connection experiments of his own, in which an iron containing 2.33 per cent. of sulphur was smelted first with a lime-slag, and afterwards with a slag in which the chemical equivalent of magnesia had been substituted for lime—the removal of sulphur in the latter case being smaller (yet not much smaller) than in the former.

On the other hand, there are instances in which magnesian slags have been used with success. Thus Mr. Frank Firmstone‡ has published tables from long practice in Eastern Pennsylvania and elsewhere which show that "for about the same content in silicon the iron made with dolomite is pretty regularly lower in sulphur than that made with limestone." Mr. Firmstone cites other authorities for the same experience, and appeals to the general practice in the Lehigh valley.

Mr. W. B. Phillips§ says that, in Alabama, "the use of dolomite was a decided advantage, especially in the elimination of sulphur."

Many other authorities to the same effect could be quoted at length;‖ but enough has been given to show that there is some difference of opinion and practice regarding the use of magnesian slags. A careful study of what has been written on the subject leads to the belief that other conditions may have

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* *Elements of Metallurgy*, p. 199.

† *Handb. der Eisenhüttenkunde*, Leipzig, 1893, p. 291.

‡ *Trans.*, xxiv., 498 (Oct., 1894).

§ "Iron-Making in Alabama," *Rep. Ala. Geol. Survey* for 1896, p. 58.

‖ The following are a few out of many to which the writer has had access: E. A. Uehling, "Dolomite as a Flux for Blast-Furnace Use," *Proc. Ala. Sci. Soc.*, vol. iv., p. 24; also in *Rep. Ala. Geol. Survey* for 1896; F. Bangenbach. *Berg-u. Hüttenm. Zeitung*, vol. liv., p. 205 (commented upon in *Jour. I. and S. Inst.*, No. ii., 1895, p. 471).

affected, in many instances, the results reported. At all events, it seemed to the writer pertinent and desirable to make a series of laboratory-experiments, designed to determine directly, if possible, under uniform conditions, the desulphurizing action of lime-magnesia silicates, carrying various definite amounts of magnesia, when these silicates were fused together with sulphurous cast-iron.

The experiments were made as follows: Quantities of one and the same iron were melted in carbon-lined (brasqued) crucibles, with silicates of calcium and magnesium, and the resultant iron was analyzed for sulphur. These conditions represent, in a measure, those existing in the crucible of an iron blast-furnace; that is, we have molten cast-iron lying quiescent in contact with an excess of carbon and covered with a blanket of slag. The iron was in the form of fair-sized shots, which ran down through the slag as they melted, thus securing intimate contact between the iron and the accompanying silicate.

The pure cast-iron used in these experiments was prepared by carburizing, in a graphite crucible, some Swedish wrought-iron,* brand (·S·), adding the sulphur in the form of iron sulphide, and silicon in the form of carborundum. The molten iron was poured into a large tank of water through a screen, with four meshes to the linear inch; the iron was thus granulated, putting it into a form convenient for weighing.

The slag-making materials were lime (CaO), "C.P. from marble," magnesia (MgO), "pure," and silica (SiO_2), "nat. praep. pure," purchased from the chemical firm of Eimer & Amend. All were well pulverized.

The proper mixture to form a slag having been made, it was pressed down solidly into the crucible, and the iron shots were placed on top. The crucibles so filled were heated in a furnace using illuminating gas and a forced blast. The temperature obtainable was from 1400° to 1550° C., as indicated by Le Chatelier's thermo-electric pyrometer. The crucibles remained in the furnace for three hours, after which the charges were poured into water, in the manner described above.

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* I am under obligations to Mr. N. Lilienberg, of New York City, for kindly furnishing me with this iron.

Experiment No. 1.

Three portions of iron of 100 grammes each were melted with

(*a*). 100 grammes of, . . .	36 CaO	16 MgO	39 SiO_2
	(40.19)	(12.85)	(46.96)
(*b*). 150 " . . .	28 CaO	24 MgO	39 SiO_2
	(32.06)	(19.77)	(48.17)
(*c*). 100 " . . .	20 CaO	32 MgO	39 SiO_2
	(23.51)	(27.06)	(49.43)

The first line of each section in the above table gives the chemical composition of the silicate; and under each molecular symbol the percentage of the substance in the mixture is given in parenthesis.

The sulphur percentages in the above iron were:

	Before Fusion.	After Fusion.	Percentage of Sulphur Removed.
(*a*), ...	0.56	0.061	89.0
(*b*), ...	0.56	0.254	54.6
(*c*), ...	0.56	0.162	71.0

Experiment No. 2.

Two portions of iron of 100 grammes each were melted with

(*a*). 150 grammes of, . . .	9 CaO	4 MgO	13 SiO_2
	34.75	11.11	54.14
(*b*). 150 " . . .	7 CaO	6 MgO	13 SiO_2
	27.63	17.04	55.33

The sulphur percentages in this iron were:

	Before Fusion.	After Fusion.	Percentage of Sulphur Removed.
(*a*), ...	0.56	0.336	40.0
(*b*), ...	0.56	0.320	42.8

Experiment No. 3.

Two portions of iron of 100 grammes each were melted with

(*a*). 150 grammes of, . . .	28CaO	8 MgO	45 SiO_2
	34.02	7.00	58.98
(*b*). 100 " . . .	12 CaO	24 MgO	45 SiO_2
	15.42	22.20	62.38

The sulphur percentages in this iron were:

	Before Fusion.	After Fusion.	Percentage of Sulphur Removed
(a), ...	0.56	0.369	34.1
(b), ...	0.56	0.454	18.9

Experiment No. 4.

Two portions of iron of 100 grammes each were melted with

(a). 100 grammes of, . .	11 CaO	MgO	18 SiO_2
	35.33	2.31	62.36
(b). 100 " . .	9 CaO	3 MgO	18 SiO_2
	29.44	7.06	63.50

The sulphur percentages in this iron were:

	Before Fusion.	After Fusion.	Percentage of Sulphur Removed.
(a), ...	0.56	0.376	32.8
(b), ...	0.56	0.272	51.4

Tabulating the results obtained above, and giving the values obtained by duplicate analyses, we have:

TABLE I.—*Sulphur Contents of Resultant Iron.*

The iron used contained initially 0.56 per cent sulphur. The ratio given in the upper line of the table is that of oxygen in bases to oxygen in acid (SiO_2).

Experiment No.	1.	2.	3.	4.
Ox. ratio of	1:1.5	1:2	1:2.5	1:3
Silicate.	Sulphur. Per cent.	Sulphur. Per cent.	Sulphur. Per cent.	Sulphur. Per cent.
Low MgO....................	0.061 0.061	0.336 0.337	0.377 0.361	0.385 0.367
Medium MgO	0.255 0.254			
High MgO..................	0.166 0.198 0.123	0.315 0.325	0.456 0.453	0.267 0.277

TABLE II.—*Percentages of CaO and MgO Corresponding to Table I.*

Experiment No.	1.	2.	3.	4.
Ox. ratio of................	1 : 1.5	1 : 2	1 : 2.5	1 : 3
Silicate.	Per cent.	Per cent.	Per cent.	Per cent.
Low MgO..................	CaO 40.19 MgO 12.85	CaO 34.75 MgO 11.11	CaO 34.02 MgO 7.00	CaO 35.33 MgO 2.31
Medium MgO............	CaO 32.06 MgO 19.77			
High MgO................	CaO 23.51 MgO 27.06	CaO 27.63 MgO 17.04	CaO 15.42 MgO 22.20	CaO 29.44 MgO 7.06

Remarks.

A more extended investigation would doubtless be necessary before any final deductions could be made. Table I. indicates, however, the well-known law, that the more basic the slag, the greater its sulphur-removing power. For in going from the right to the left of the table, that is, from the more acid to the more basic silicates, there is a decrease in the residual sulphur-values, indicating a greater sulphur-removal. The value given in the lower right-hand corner of Table I. is, however, an exception to the above statement.

Under experiment No. 1 it appears that the high-lime slag removed most sulphur; that the highly magnesian slag removed somewhat less; and that the "medium" slag removed still less. This may indicate that we can adjust the ratio of lime to magnesia so as to produce a silicate with a desired sulphur-absorbing power.

In experiment No. 2 there is hardly any difference in the values. The percentage of magnesia did not vary much.

In experiment No. 3 the high-lime silicate removed the most sulphur, even allowing for its greater amount (150 grammes against 100 of the highly magnesian slag).

In experiment No. 4 the highly magnesian slag removed most sulphur; but, as in No. 2, the percentage of magnesia does not vary in this experiment to any considerable degree. The variation in the percentage of magnesia is limited by the capacity of the furnace to melt the silicates; the extremes here given were determined by experiment to be the best.

It may be that the high-lime slag has a maximum desulphurizing action for a certain acidity, while for another degree of acidity the high-magnesia slag is best. Further experiments would shed light upon this suggestion.

It is to be noticed that in experiments Nos. 1 and 3, in which the greatest variation in the percentage of magnesia occurs, the greatest quantity of sulphur was removed by the slag high in lime. Since, in these experiments, the percentage of magnesia varies within wider limits than in the other two, greater weight must be given to their results. Hence, it might appear that slags high in lime are the most efficient desulphurizers.

The results of this investigation, however, do not warrant the assertion of a final conclusion. More elaborate experiments, operating upon larger quantities of material, and with a greater variety of slags, would give evidence, no doubt, which would permit sound and definite deductions.

Supplementary Note.—The sulphur-determinations above reported were made by the *aqua regia* method. Considerable difficulty was experienced in getting the iron into solution. The shots of metal became quickly coated with a layer of silica, which protected them from the further action of the acid; and resort was had to the use of hydrofluoric acid, in order to obtain solution in a reasonable length of time. This difficulty led me to suppose that, at the high temperature employed, some silicon was reduced from the slag and entered the iron. If this was the case, the acidity of the various silicates was altered somewhat. It is judged, however, that this possible change in acidity was not great enough to affect materially the results obtained.

As has been remarked, two or three crucibles were placed in the furnace and heated at the same time. Hence the temperature necessary to melt the most refractory silicate had to be employed. The most fusible slag was therefore heated to a degree above that required for proper fusion. This introduces another variable into the discussion. The only way to avoid this difficulty would have been to heat each charge separately —a course which, in these experiments, time did not permit.

Nickel-Steel; A Synopsis of Experiment and Opinion.

BY DAVID H. BROWNE, CLEVELAND, OHIO.

(California Meeting, September, 1899.)

INTRODUCTION.

THE trite maxim that man is a tool-using animal might now-a-days be amended by saying that man is a tool-choosing animal. The chipped flint, at first all-sufficient, gave way to hammered bronze, and that, in turn, to wrought-iron and steel. As our knowledge of metals increases, we learn to specialize; we temper and anneal; we alloy and intermix; and we fashion for ourselves a metal suitable to our necessities. The knowledge of the properties and uses of the various metals and their alloys has become the capital of every constructive engineer, and the currency of every intelligent brass-founder and blacksmith. From year to year, the specifications of the designer become more rigid, and the steel-maker is forced to study more closely the qualities obtainable by changing the treatment, or altering the composition, of his metal.

Of making alloys there is no end. We have heard much, during the last decade, of manganese-steel and chrome-steel, of aluminum and tungsten, of titanium- and silicon- and copper-steels, and of every conceivable union into which steel could be coerced or cajoled. Without denying to each of these alloys novel and valuable properties, it must be admitted that, of all alloys, the one which shows the greatest range of adaptability, and has met the largest measure of popular approval, is nickel-steel. Introduced to public notice by Mr. Riley, in 1889, its field of usefulness has been rapidly enlarged, until, at the present day, the use of nickel-steel is as thoroughly recognized as that of carbon- or manganese-steel.

Concerning the properties of nickel-steel numerous articles have appeared in the technical journals. For the man in a hurry, who wishes to look up the properties and limitations of nickel-steel, these articles might almost as well be in the lost

library of Alexandria. The purpose of this paper is to present in systematic form a summary of the best that has been written upon this subject. Some hitherto unpublished data have been secured; the opinions of manufacturers and users have been collected; and the various uses to which nickel-steel is applied have been investigated and recorded.

My thanks are due to Mr. E. F. Wood, of The Carnegie Steel Co.; Mr. H. F. J. Porter, of The Bethlehem Steel Co.; Mr. G. H. Chase, of The Midvale Steel Co.; Mr. Henry Souther, of The Pope Manufacturing Co.; Mr. H. J. Williams, of the Damascus Tool Co.; and Mr. H. K. Landis, of New York, for procuring new data, and for kindly aid in obtaining comparative tests. It is hoped that the material thus collated may prove interesting and useful to all who are in any way concerned with the manufacture and use of steel.

Physical Qualities of Nickel.

The three metals, iron, manganese and nickel, form a group having remarkably similar physical and chemical qualities. In specific weight, atomic weight, atomic volume, melting-point and color, these metals have a close family resemblance. While an examination of any one of these reveals no remarkable physical superiority over the others, the fact remains that each seems to exercise, in an alloy, a beneficial effect upon the other two. The addition of small amounts of these metals to one another produces alloys much superior in physical qualities to the pure metals. Manganese increases the strength of pure nickel; and both manganese and nickel greatly increase the strength of pure iron.

The most careful investigations yet made upon the alloys of nickel and iron are those of the committee appointed in 1891 by the Berlin "Society for the Encouragement of Technical Industry." The reports of this committee, compiled by Professors Wedding and Rudeloff, and published from time to time in the *V ' r' · · des Vereins zur Beförderung des Gewerbfleisses*, will form, when completed, a systematic record of the properties of the alloys of nickel and iron. As these papers have not yet been translated into English, and as the original reports are not easily accessible in the United States, I have given, in the following pages, very full excerpts from them.

For these investigations, Professor Rudeloff procured samples of the best commercial nickel and of iron almost free from carbon and other impurities. These metals were cast into bars, rolled into rods and straps, and tested in the raw condition, and also after hammering and annealing. A series of alloys of nickel with pure iron was then made; and a complete series of tests was instituted, to show the effect of nickel in amounts varying from zero to 98 per cent. The commercially pure nickel test-bars, after melting and casting, were found by analysis to contain:

	Per cent.
Nickel,	98.13
Cobalt,	1.15
Iron,	.43
Silicon,	.08
Magnesium,	.11

The physical properties of this pure nickel in the bar as cast and after rolling into flat bars were as follows:

TABLE I.—*Physical Properties of Nickel Bars.*

Commercial Nickel.	Limit of Proportionality. Lbs. per Sq. In.	Elastic Limit. Lbs. per Sq. In.	Ultimate Strength. Lbs. per Sq. In.	Prop'rtion Elastic to Ultimate Per cent.	Modulus of Elasticity.	Elongation. Per cent.
Cast bars	5,119	12,557	40,669	38	23,989,140	18.2
Rolled: Raw	9,243	21,045	72,522	29	29,506,500	43.9
Rolled: Annealed	17,064	18,059	72,806	25	26,870,800	48.6
Rolled: Quenched	....	16,921	71,860	24	....	45.0

For purposes of comparison, the physical properties of the pure iron (containing 0.07 per cent. carbon) used for the preparation of the nickel-iron alloys, are here given:

TABLE II.—*Physical Properties of Iron Bars.*

Pure Iron.	Limit of Proportionality. Lbs. per Sq. In.	Elastic Limit. Lbs. per Sq. In.	Ultimate Strength. Lbs. per Sq. In.	Prop'rtion Elastic to Ultimate. Per cent.	Modulus of Elasticity.	Elongation. Per cent.
Cast bars	8,532	20,761	46,072	45	32,030,550	36.8
Rolled: Raw	20,761	31,568	50,196	63	28,795,500	42.3
Rolled: Annealed	21,756	32,848	44,793	73	29,151,000	49.8
Rolled: Quenched	9,100	48,774	69,962	70	31,568,400	27.8

Hadfield, in his recent paper on nickel-iron alloys,* gives the following tests of nickel:

TABLE. III.—*Cast and Forged Nickel* (98.8 *Per Cent. Nickel*).

Test-Bar.	Elastic Limit Lbs per Sq. In.	Tensile Strength.	Elong in 2 in. Per cent	Contr of Area.	Fracture.
Cast, unannealed	24,640	36,400	4.5	9.76	Granular.
Forged, unannealed........	31,360	72,128	45.5	57.04	Fibrous, silky.
Forged, annealed............	15,680	70,000	54.	52.5	Fibrous, silky.

The physical tests of metallic nickel furnish no explanation of its remarkable effects when alloyed with iron. Nickel has a specific weight of 8.3 to 8.9; its atomic weight is 58.6, and its atomic volume 6.60. It melts at about the same temperature as steel, its melting-point depending on the amount of carbon present. The specific heat of nickel is about 0.108 to 0.110. Nickel is slightly stronger than pure iron, somewhat harder, and much less easily oxidized by moisture and steam. It can be heated to redness without perceptible oxidation, is slowly soluble in hydrochloric and sulphuric acid, and is readily soluble in dilute, but remains passive in concentrated, nitric acid.

Nickel can retain carbon, both as graphite and as amorphous carbon; it can absorb silicon, and will alloy in any proportion with iron. It absorbs oxygen when melted, and requires the addition, when molten, of about 0.1 per cent. of magnesium, in order to form a sound casting.

Alloyed with iron and steel, nickel produces a remarkable series of metals, the physical qualities of which will be taken up in systematic order.

II.—PHYSICAL QUALITIES OF NICKEL-STEEL.

Elasticity.

Nickel-steel is most emphatically distinguished from simple steel by its high elastic strength. While this factor is, to a certain extent, shown by the test for elastic limit, it must

* "Alloys of Iron and Nickel," *Proceed. Inst. Civil Engrs.*, London, vol. cxxxviii., Part iv., 1899, p. 1.

not be confounded therewith. The strength of a man may be measured in three ways. We may first determine the actual load which his body, rigidly suspended, could sustain without actual rupture. This load would correspond to the ultimate tensile strength of steel. Secondly, we may determine the actual load which, with the utmost bodily exertion, he can sustain for a few seconds. This would correspond to the elastic limit of steel as usually tested by "drop of beam." Thirdly, and with entire justice, we may determine the amount of work which he can daily and regularly perform without undue fatigue and with no injurious strain to any bodily organ. This is properly compared to the elastic or live strength of steel, as measured by the French "limit of proportionality," or by the resistance of the bar to numerous and rapidly alternating strains. It is a well-known fact that rupture may be produced by numerous applications of a load below the elastic limit of the metal; and such an occurrence in the case of shafts and axles is vaguely ascribed to the "fatigue of metals" in service. This term conveys a larger scientific truth than is generally appreciated; and in some testing-works it is customary to measure more or less empirically the endurance of metals with regard to what may be termed molecular fatigue. If steel were a homogeneous metal, every applied load, less than the elastic limit, should produce a deformation proportionate to the load; and upon the removal of the load the test-piece should regain its original dimensions. If, for example, on a steel rod under tension, a load of 1000 pounds produces a stretch of one thousandth of an inch, then 2000 pounds should produce double this stretch; and 4000 pounds should cause four times the deformation produced by 1000. If we find that by successive increments of 1000-pound loads we get regularly increasing stretch, proportioned to the load, up to 10,000 pounds, but that a load of 11,000 pounds produces twelve-thousandths of an inch stretch, it is evident that, at 10,000 pounds' load, the ratio between strain and stretch changes. This point is called by the French and German investigators the "limit of proportionality." It is far below the elastic limit of the test-piece. In the case we have outlined, the load might be increased to 20,000 pounds before a permanent set would be produced; but it is very evident that the elastic strength of a metal is more ac-

curately measured by the limit of proportionality, where a molecular fatigue begins, than by the commonly known "elastic limit," where an actual molecular distortion takes place.

The addition of nickel to iron and steel increases the ultimate strength, and, to a higher degree, the elastic limit; while its greatest influence is shown on the limit of proportionality. Some exceedingly interesting experiments conducted by Prof. Rudeloff,* in Berlin, on the alloys of varying amounts of nickel with almost chemically pure iron, bring out this feature very strikingly.

TABLE IV.—*Elastic Strength of Iron-Nickel Alloys.*

Iron containing Nickel. Per cent.	Limit of proportionality. Pounds per square inch.	Iron taken as standard.
0	8,532	100
0.5	8,816	103
1	10,238	120
2	14,504	170
3	22,894	268
4	23,605	275
5	27,871	326
8	32,421	380
15	22,752	266

An alloy of 8 per cent. of nickel with pure iron has 3.8 times the elastic strength of pure iron. With higher percentage of nickel the limit of proportionality decreases, the greatest effect being shown at 8 per cent. The effect of nickel on the elasticity is not changed by the presence of carbon; and for this reason nickel-steel shows, as Mr. Davenport says, "that combination of high elastic strength and toughness" which distinguishes it from simple steel.†

At the Bethlehem Steel Works, in Bethlehem, Pa., and at the Pope Tube Works, in Hartford, Conn., it is customary to measure the elastic strength of metals by their resistance to numerous and rapidly alternating flexures. The apparatus consists of an ordinary lathe, with a ball-and-socket chuck, into which one end of the test-piece is fastened, while the other end is supported by a collar in the tail-stock. A roller-bearing

* *Verein zur Beförderung des Gewerbfleisses*, Berlin, February, 1896.

† "Steel for Marine Engine Forgings," *Cassier's Magazine*, Aug., 1897, p. 525.

ring encircles the test-piece at its center, and from this depends an adjustable weight.

" Assume," says Mr. Souther, " that in all cases the specimens are annealed, and by 'annealed' I mean treated at the best annealing-temperature for each grade of steel. Take a 0.10 per cent. carbon-steel as a basis, loaded say to two-thirds its elastic limit, maximum fiber-stress; assuming that this, under these circumstances, will withstand 100,000 revolutions, then a 0.25 carbon-steel will stand somewhere in the neighborhood of 200,000; a 0.50 carbon, about 400,000; and nickel-steel (0.25 carbon, 5 nickel), in the neighborhood of 1,000,000 revolutions."*

In these tests the live strength or working-life of the metal is shown, and a very close estimate can be made of the value of a metal under normal conditions of work.

Elastic Limit and Ultimate Strength.

The elastic limit and tensile strength of steel are so much influenced by the percentage of carbon present, and by the mechanical or heat-treatment to which the metal has been subjected, that it is of the utmost importance to secure for comparison test-pieces in which all modifying conditions, except the percentage of nickel, are identical.

The most complete tests made up to the present time are those of Rudeloff, on almost carbon-free nickel-alloys; and of Hadfield on nickel-steels of very low and almost uniform carbon-contents.

TABLE V.—*Strength of Nickel-Iron Alloys.*—(Rudeloff.)

Iron Containing Nickel Per cent.	Elastic Limit. Lbs. per Sq. In.	Elastic Limit. Compared with Iron as Standard	Tensile Strength. Lbs. per Sq. In.	Tensile Strength. Compared with Iron as Standard.
0	20,761	100	46,072	100
1	23,605	113	47,921	104
2	28,724	137	52,614	114
3	34,128	184	57,733	125
4	38,251	184	57,733	125
5	46,215	222	63,421	137
6	62,852	303	79,916	173

Mr. Hadfield's experiments on steels containing very low

* Mr. Henry Souther, Engineer Pope Tube Co., private communication.

carbon (0.15 to 0.20), with different amounts of nickel, show the following results:*

TABLE VI.—*Annealed Test-Bars (Cast).*

Nickel. Per cent.	Elastic Limit Lbs. per Sq. In.	Tensile Strength. Lbs per Sq. In.	Elongation. Per cent.	Contraction. Per cent.
0.27	44,800	62,720	37	52
0.51	47,040	60,480	41	63
0.95	44,800	60,480	41	63
1.92	49,280	69,440	36	53
3.82	56,000	73,920	35	55
5.81	62,720	82,880	33	51
7.65	67,200	100,800	26	41
9.51	71,680	125,440	2	2
11.39	100,800	199,360	12	26
15.48	....	152,320	1	1
19.64	100,800	194,880	5	4
24.51	56,000	174,720	14	8
29.07	35,840	82,880	48	51
49.65	33,600	80,640	49	53

According to the experiments of Rudeloff, the addition (up to 5 per cent.) of nickel to pure iron produces for each 1 per cent. of nickel added a gain of 5090 pounds in the elastic limit, and a gain of 3469 pounds in the ultimate strength. Hammered test-bars of the same material, show a gain of 5403 pounds elastic, and 5175 pounds ultimate strength for each 1 per cent. of nickel added. Fig. 1 represents the approximate curve of increase in elastic limit due to 1 per cent. of nickel added to steel of different carbon-contents.

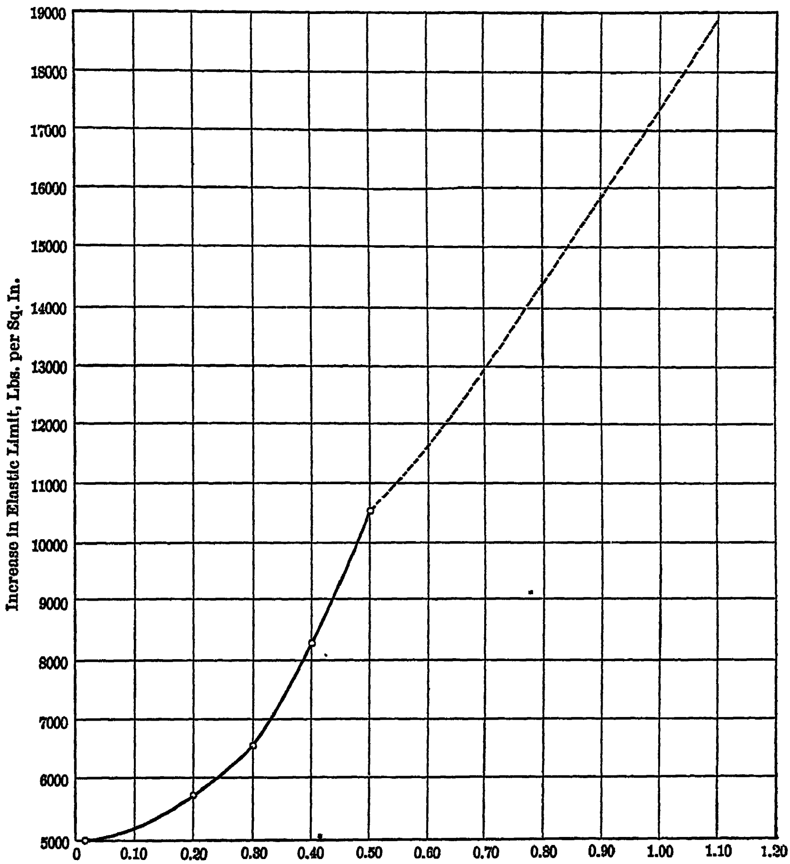
If nickel be added to the soft steels, it raises the elastic limit and the ultimate strength in much the same proportion as in pure iron. Carbon does not therefore prevent the influence of nickel; but, as will be explained later, nickel has a very marked effect upon the carbon present.

The proportion of nickel commonly used in soft steels for armor and for engine-forgings is from 3 to 3.5 per cent. This percentage of nickel, alloyed with an open-hearth steel of 0.25 per cent. carbon, produces a metal equal in elastic limit and tensile strength to a similar open-hearth steel of 0.45 carbon without nickel. In other words, 3 per cent. of nickel, added to a soft steel, has the same effect on the strength as the intro-

* "Alloys of Iron and Nickel," *Proc. Inst. Civil Engrs.*, London, vol. cxxxviii., Part iv., 1889, p. 12.

duction of 0.20 per cent. of carbon would have, while the ductility remains at the figure usually found in the lower-carbon steel. Protective deck-steel of 0.45 carbon and no nickel will have a tensile strength of 90,000 pounds, with 15 per cent. elongation in four diameters; while a 0.25-carbon steel, with

FIG. 1.



APPROXIMATE CURVE OF INCREASE IN ELASTIC LIMIT DUE TO ONE PER CENT OF NICKEL

3 per cent. of nickel, will have the same tensile strength of 90,000 pounds, with 20 per cent. of elongation, in four diameters.*

On all the low-carbon steels the addition of nickel seems to produce remarkably uniform results. A flange-steel (0.10 car-

* Mr. E. F. Wood, Carnegie Steel Works. Private communication.

bon and no nickel), rolled into sheets, gave 35,243 pounds elastic and 54,450 pounds ultimate strength. The addition of 2.7 per cent. of nickel brought these figures up to 47,080 and 65,750 pounds respectively.* This shows a gain of 4384 pounds on elastic limit and 3814 pounds on ultimate strength for each 1 per cent. of nickel added.

Steel tubing (of 0.25 carbon and no nickel) has very closely 40,000 pounds elastic limit and 70,000 pounds ultimate strength. The addition of 5 per cent. of nickel raises the elastic limit to 60,000 and the ultimate to 95,000 pounds per square inch—the gain for each 1 per cent. of nickel added being 4000 pounds on the elastic and 5000 pounds on the ultimate strength.†

Rolled steel, of 0.14 carbon, tested by Mr. Allan, of Glasgow, showed the following comparison with nickel-steel:

Carbon. Per cent.	Nickel. Per cent.	Elastic Limit. Lbs. per Sq. In.	Ultimate Strength. Lbs. per Sq. In.
0.14	none	27,552	63,168
0.14	3	43,008	73,696

The gain was 5485 pounds on the elastic limit and 3509 pounds on the ultimate strength for each 1 per cent. of nickel added.‡

On homogeneous irons and low-carbon steels, not subjected to heat-treatment, it appears that each 1 per cent. of nickel added, up to 5 per cent., causes an increase of about 5000 pounds elastic limit and 4000 pounds tensile strength.

With higher percentages of carbon, the influence of nickel is divided between its action *per se*, producing a gain in toughness and strength, and its action on the carbon present, modifying to a certain extent the original influence of nickel.

High percentages of nickel tend to throw any carbon in the alloy into the graphite state. A 30 per cent. nickel-steel, containing 1 per cent. of carbon, will have 0.80 carbon in the shape of graphite.§ A 25 per cent. nickel-steel retains carbon

* Canadian Copper Co.'s experiments.

† Mr. Henry Souther, Engr. of Tests, Pope Mfg. Co. Private communication.

‡ Beardmore, "Nickel-Steel as an Improved Material," etc.

§ Rudeloff, *Verein zur Beförderung des Gewerbfleisses*, Heft I., p. 85.

in a state in which the metal is not influenced by tempering.* Carbon existing in pure nickel is almost entirely in the graphitic condition; and high percentages of nickel tend to throw the carbon into this state. With lower percentages of nickel, the effect is to change part of the carbon from cement-carbon to hardening-carbon, thereby rendering the metal exceedingly sensitive to heat-treatment.†

The Bethlehem Steel Company gives the following table of comparative tests of nickel steels and simple steels on oil-tempered, annealed forgings:‡

TABLE VII.—*Comparative Tests of Nickel-Steel and Simple Steel Forgings.*

Composition of Forgings.	Elastic Limit. Lbs. per Sq. In.	Tensile Strength Lbs. per Sq. In	Elongation. Per cent.	Contraction of Area. Per cent.
No nickel, 0.20 carbon	28,000	55,000	34	60
3.5 per cent. nickel, 0.20 carbon	48,000	85,000	26	55
Influence of 3.5 per cent. nickel	+20,000	+30,000	—8	—5
" " 1 per cent. nickel	+5,714	+8,571		
No nickel, 0.30 carbon	37,000	75,000	30	50
3.5 per cent. nickel, 0.30 carbon	60,000	95,000	22	48
Influence of 3.5 per cent. nickel	+23,000	+20,000	—8	—2
" " 1 per cent. nickel	+6,571	+5,714		
No nickel, 0.40 carbon	43,000	85,000	25	45
3.5 per cent. nickel, 0.40 carbon	72,000	110,000	18	40
Influence of 3.5 per cent. nickel	+29,000	+25,000	—7	—5
" " 1 per cent. nickel	+8,285	+7,142		
No nickel, 0.50 carbon	48,000	95,000	21	40
3.5 per cent. nickel, 0.50 carbon	85,000	125,000	13	32
Influence of 3.5 per cent. nickel	+37,000	+30,000	—7	—8
" " 1 per cent. nickel	+10,570	+8,571		

This table is exceedingly interesting, as showing that the effect of nickel on the elastic limit increases as the carbon increases.

* Cholat and Harmet, *Oesterr. Zeitsch. für Berg- und Hüttenwesen*, 1894, p. 543.

† Mr. Chase, Midvale Steel Co. Private communication.

‡ Mr. R. W. Davenport, Mr. H. F. J. Porter and Mr. Hart. Private communication.

In the 0.20-carbon steel, the gain on elastic limit due to 1 per cent. of nickel is 5714 pounds; while in the 0.50-carbon steel, the gain on elastic limit, due to 1 per cent. of nickel, is 10,570 pounds.

Mr. McDonald, of the Crescent Steel Company, of Pittsburgh, reports a test of nickel in forged steel of 1.10 per cent. carbon, as follows:

Composition.	Elastic Limit.	Tensile Strength.
No nickel, 1.10 carbon,	57,700	112,452
1.65 per cent. nickel, 1.10 carbon,	88,980	146,250
Gain due to 1.65 per cent. of nickel,	31,280	33,798
" to 1 " "	18,957	20,484

The influence of nickel on both elastic and ultimate strength seems, therefore, to increase with the percentage of carbon; or, in other words, high-carbon steels show a greater gain from the addition of nickel than low-carbon steels. While the above data are too few to base accurate comparisons upon, still the reports made by the Bethlehem Iron Company coincide very well with the results given by other steel works; and as a basis for future comparison the gains due to 1 per cent. of nickel have been plotted in the curve shown in Fig. 1.

Cholat and Harmet found that in iron alloys the greatest strength was obtained by the addition of 15 per cent. of nickel. Taking this 15 per cent. alloy, and adding to it varying amounts of carbon, they found the greatest strength was produced by 0.30 carbon, at which percentage a tensile strength of 213,400 pounds was obtained. The same alloy (0.30 carbon, 15 nickel), oil-tempered, showed an elastic limit of 166,300, and an ultimate strength of 277,290 pounds per square inch.*

Experimenting on steel containing from .15 to .20 carbon, Mr. Hadfield finds the greatest strength is produced by the addition of 12 to 15 per cent. of nickel. Cast test-bars, not annealed, containing 11.39 per cent. nickel, showed a tensile strength of 210,560 pounds per square inch, the same figure being also given by a steel containing 15.48 per cent. nickel.†

* Cholat and Harmet, *Oesterr. Zeitsch. für Berg- und Hüttenwesen*, 1894, p. 534. Abridged in *Scientific American*, Jan. 8, 1897.

† Hadfield, "Alloys of Iron and Nickel," *Proc. Inst. Civil Engrs.*, 1899, Part iv.

Elongation and Contraction of Area.

Nickel-steels show a slight decrease in elongation and contraction of area when compared with simple steels of the same percentage of carbon, but an increase in these measurements, when compared with simple steels of the same tensile strength or elastic limit.

A 0.25-carbon structural steel, annealed, tested by J. G. Eaton,* showed:

Carbon. Per cent.	Nickel. Per cent.	Elastic Limit. Lbs. per Sq. In.	Ultimate Strength. Lbs. per Sq. In.	Elongation. Per cent.	Reduction of Area. Per cent.
0.25	none	36,420	62,410	26.25	58.5
0.25	3.3	59,500	84,640	24.50	54.0

Comparing steels of equal carbon, it appears that nickel produces a slight decrease in elongation and contraction of area.

If steels of equal tensile strength be compared, nickel-steel will show greater ductility than carbon-steel:†

Carbon. Per cent.	Nickel. Per cent.	Elastic Limit. Lbs. per Sq. In.	Ultimate Strength. Lbs. per Sq. In.	Elongation. Per cent.	Reduction of Area. Per cent.
0.20	3.5	45,000	85,000	26	50
0.40	none	43,000	85,000	25	40

On protective deck-plates, simple steel of 0.45 carbon will show 90,000 pounds tensile strength and 15 per cent. elongation in a 2-inch piece; while a 0.20-carbon steel, with 3 per cent. nickel, having the same tensile strength of 90,000 pounds, will give 20 per cent. of elongation in the same length.

"With a given tensile strength," says Mr. R. W. Davenport,‡ "nickel increases somewhat the elongation, and to a greater degree the contraction of area."

It may therefore be taken as a rule that, as compared with simple steels of the same tensile strength, a 3 per cent. nickel-steel will have from 20 to 30 per cent. greater elongation; while, as compared with simple steels of the same carbon-percentage, the nickel-steel will have about 40 per cent. greater tensile strength, with practically the same elongation and re-

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* Commander J. G. Eaton, "The Advantages of Nickel-Steel over Carbon-Steels."

† Mr. E. F. Wood, Carnegie Steel Co. ‡ *Cassier's Magazine*, Aug., 1897.

duction of area. This relation of ductility to tensile strength holds good only for the usual nickel-steels, containing up to 5 per cent. of nickel.

In the alloys of nickel with pure iron, the experiments of Wedding and Rudeloff, and those of Cholat and Harmet, Guillaume and Moulan, have shown a different relation.

The figures obtained by Rudeloff for cast bars of alloys of nickel, with almost pure iron, show the following relations between elastic limit, ultimate strength and ductility:

TABLE VIII.—*Strength and Ductility of Nickel-Iron Alloys.*

Nickel. Per cent.	Elastic Limit. Lbs. per Sq. In.	Ultimate Strength Lbs. per Sq. In.	Elongation. Per cent.
0	20,761	46,072	29.7
1	23,605	47,921	26.4
2	28,724	52,614	22.7
3	34,128	57,733	20.1
4	38,251	57,733	17.6
5	46,215	63,421	10.8
8	62,852	79,916	9.6
16	....	58,302	0.6
30	....	14,077	2.2
60	17,775	53,751	36.1
93	15,357	47,210	19.0
98	12,940	43,371	17.1

From this it will be seen that in alloys of nickel with iron containing little or no carbon the strength of the alloy increases with each rise in nickel up to 8 per cent., while the ductility decreases up to 16 per cent. Beyond this point, and up to 60 per cent., the increase of nickel causes an increase both in ductility and strength.*

At about 25 per cent. of nickel it seems that a peculiar molecular change is produced. A wire with 24 per cent. of nickel is as soft and ductile as copper,† and a 27 per cent. nickel-steel shows 47 per cent. of elongation, with a tensile strength of 100,000 pounds per square inch.‡ Riley states§ that 25 per cent. nickel-steel, containing 0.27 carbon, gave an elongation of 29 per cent., with a tensile strength of 102,600 pounds per square inch; while nickel-steel, with 25 per cent.

* See effect of nickel on hardness, p. 593.

† Guillaume, *Recherches sur les Aciers au Nickel.*

‡ J. C. Danziger, *Detroit Eng. Soc.*, June 19, 1896.

§ J. Riley, *Jour. Iron and Steel Inst.*, No. 1, 1889, p. 48.

of nickel and 0.82 of carbon, gave 40 per cent. of elongation, with a tensile strength of 94,300 pounds. In this case it will be noticed that a large increase in carbon gave a large increase in ductility, with a slight drop in tensile strength. Cholat and Harmet state that in 25 per cent. nickel-steels, elongation and reduction of area rise with increase in the carbon-content, and the tensile strength remains high.*

These tests show that the steels containing high percentages of nickel are entirely different in physical properties from the low-nickel steels commonly used in mechanical engineering.

Proportion of Elastic Limit to Ultimate Strength.

In low-carbon simple steels the elastic limit is about 50 per cent. of the ultimate strength. The addition of nickel to soft steel and homogeneous iron increases the proportion of elastic limit to ultimate strength, as is shown by the following tables, taken from Rudeloff's experiments:†

TABLE IX.—*Proportion of Elastic to Ultimate Strength in Iron-Nickel Alloys.*

Nickel Per cent.	Proportion Elastic to Ultimate. Per cent.
0	45
1	49
2	55
3	59
4	66
5	73
8	79

M. Moulan,‡ of the Société Cockerill, at Seraing, Belgium, in experimenting on an alloy of pure iron with 7.5 per cent. of nickel, found that in soft iron the ratio of elastic limit to ultimate strength is 55 per cent.; while in 0.55-carbon steel the ratio is 51 per cent.; and in the alloy of homogeneous iron with 7.5 per cent. of nickel, the ratio is 91 per cent. of the ultimate. The same samples having been oil-tempered and annealed at 500° C., the ratios were found to be 65 for iron, 74 for steel, and 96 for the ferro-nickel alloy. This high propor-

* *Oesterr. Zeitsch. für Berg- und Hüttenwesen*, 1894, p. 543.

† *Verein zur Beförderung des Gewerbfleisses*, Berlin, 1896.

‡ *Industries and Iron*, Nov. 2, 1894.

tion of elastic limit to ultimate strength had been attained without loss of ductility, since in the oil-tempered and annealed sample the elongation of the ferro-nickel alloy was 12.2 per cent.

"The ratio of elastic limit to tensile strength (in steel) can be increased by tempering (*i.e.*, hardening by sudden cooling), with subsequent annealing, and also by the introduction into the metal of a proper amount of certain unusual ingredients, notably nickel."*

"Nickel," says Mr. Colby,† "increases the ratio between the elastic limit and tensile strength, and adds to the ductility of the steel." Tests made by Mr. Colby show that on forgings of mild steel, annealed, the ratio between elastic limit and ultimate strength is 46.4; in medium hard steel, annealed, 46.2; and in medium hard nickel-steel, annealed, 58.7 per cent.

Mr. Allan, Lloyd's Surveyor at Parkhead, Glasgow, finds the ratios as follows:

	Proportion of Elastic Limit to Ultimate Strength. Per cent.
Forged nickel steel,	64.0
" simple "	54.4
Rolled nickel "	58.3
" simple "	43.6

Mr. Beardmore states that the ratio of elastic limit to tensile strength is from 63 to 74 per cent. in 3 per cent. nickel-steel forgings.

The influence of nickel upon the strength of steel is most apparent in the elastic strength or working-capacity of the metal. If simple carbon-steel of a given tensile strength be compared with nickel-steel of the same tensile strength, it will be found that the elastic limit of the nickel-steel is from 10 to 20 per cent. greater than that of the carbon-steel. This effect of nickel upon the elastic limit and the limit of proportionality accounts for the increased working-capacity of nickel-steel and its resistance to molecular fatigue.

Influence of Mechanical Work on Nickel-Iron Alloys.

A very thorough investigation of the effect of forging, and flat- and round-rolling, on the physical properties of nickel-

* R. W. Davenport, *Cassier's Mag.*, Aug., 1897.
† A. L. Colby, *Trans. Engrs. Club*, Phila., 1897, vol. xiii.

steel has been made at the Royal Mechanico-Technical Experimental Station, at Charlottenburg, Prussia. The average results obtained are given in Table X., in which the qualities of the various alloys of nickel and iron, after rolling, are compared with their qualities in the cast bars. This table should be studied in connection with Table VIII.:

TABLE X.—*The Effect of Hot-Rolling on Nickel-Iron Alloys*—The Values in the Cast Bar taken as* 100.

Nickel. Per cent.	Elastic Limit after Rolling.	Ultimate Strength after Rolling.	Elongation after Rolling.
0	160	102	136
1	156	102	132
2	140	104	155
3	132	101	161
4	118	107	186
5	113	107	301
8	97	94	318
16	......	315	1211
60	197	164	92
95	159	172	213
98	104	175	243

From this table it will be seen that the elastic limit of the low-grade nickel-steels is not as much increased by rolling as is that of wrought-iron. The figures of increase in ultimate strength are, for the low percentages of nickel, about the same as for pure iron. The ductility of nickel-steel, however, is increased by mechanical treatment to a much greater extent than that of iron. The 16 per cent. nickel-iron alloy shows a remarkable increase in ultimate strength and ductility after rolling. The actual figures obtained were as follows:

TABLE XI.—*Tests of* 16 *Per Cent. Nickel-Iron Alloy, as Cast and as Rolled.*

	Ultimate Strength. Lbs. per Sq. Inch.	Elongation. Per cent.
Cast, ...	58,302	0.6
Rolled and annealed, ...	183,580	11.0

This extraordinary increase in the strength of a 16 per cent. nickel-iron alloy by working is corroborated by the declaration of Mr. H. J. Williams,† that an 18 per cent. nickel-steel re-

* *Verein zur Beförderung des Gewerbfleisses*, vi. and vii., 1898.

† H. J. Williams, Damascus Steel Co., Pittsburgh, Pa. Private communication.

TABLE XII.—*The Effect of Heat-Treatment on Nickel-Iron Alloys.*—(Tables from Wedding and Rudeloff.)

Elastic Limit in Pounds per Square Inch.

Percentage of Nickel.	None.	1.	2.	3.	4.	5.	8.	16.	30.	60.	93.	98.
Raw, cast..........................	20,761	23,605	28,724	34,128	38,251	46,215	62,852		17,750	17,750	15,357	15,357
Hammered........................	27,871	39,105	40,669	44,650	46,783	54,889	75,223			14,788		26,449
Hammered and annealed......	34,554	40,953	41,664	46,783	45,788	54,889	70,246			27,871		8,816
Hammered and quenched.....	46,926	50,765	56,026	87,168	105,654	137,934	161,254*			33,843		12,229
Tensile Strength in Pounds per Square Inch.												
Raw, cast..........................	46,072	47,920	52,614	57,733	57,733	63,421	79,916	58,302	14,077	53,750	47,210	40,669
Hammered........................	45,930	52,398	54,016	62,141	63,990	71,811	87,737			18,059		68,398
Hammered and annealed......	44,508	51,476	52,614	58,444	62,994	69,678	84,324			50,196		63,421
Hammered and quenched.....	65,698	76,788	79,347	112,622	136,512	183,764	161,254*			60,150		53,893

* Elastic limit and tensile strength here appear to be the same.

ceives its highest obtainable tensile strength and elasticity by hammering on the anvil from a red heat until cold.

Influence of Heat-Treatment on Nickel-Steels.

On heating simple carbon-steels to redness, and plunging them into oil, the elastic limit and tensile strength of the metal are raised, the effect being greater on the high-carbon than on the low-carbon steels. Prof. Howe, in his *Metallurgy of Steel*, gives tables showing that the tensile strength is increased by quenching from 23 per cent. in 0.10-carbon steel to 77 per cent. in 0.50-carbon steel; while, in the same samples, the elastic limit was raised by this treatment 83 per cent. in the soft and 161 per cent. in the hard steel.

In the absence of carbon, nickel itself can render iron very sensitive to heat-treatment; and in the presence of carbon the sensitiveness to heat-treatment which carbon induces is augmented by the influence of nickel. The effect of nickel alone is shown in Table XII., in which tensile tests of iron almost free from carbon, but containing nickel, are compared in four conditions: (a) cast bars; (b) hammered bars; as (1) hammered, (2) annealed and (3) quenched.

From this table it will be seen that the effects of annealing and quenching are as follows: On alloys containing 8 per cent. nickel, and less, annealing lowers to a slight extent the tensile strength and elastic limit. By quenching, the elastic limit of nickel is uniformly raised.

If the strength of the hammered and annealed bar be taken as 100, the gain in strength produced by quenching is as follows:

TABLE XIII.—*Increase of Strength in Iron-Nickel Alloys by Quenching.*

(In Percentages above the Figures for the Hammered and Annealed Bar before Quenching.)

Nickel. Per cent.	Increase in Elastic Limit. Per cent.	Increase in Ultimate Strength. Per cent.
0	36	48
1	24	50
2	34	51
3	86	93
4	131	117
5	147	164
8	130	91

These figures, from Wedding and Rudeloff,* are corroborated by the experiments of M. Moulan, of the Société Cockerill.† Comparing "homogeneous iron," containing almost no carbon, with the same metal after alloying with 7.5 per cent. of nickel, he found the gain in tensile strength and elastic limit produced by heat-treatment to be as follows:

TABLE XIV.—*Increase of Strength Produced in Iron, and in a Certain Iron-Nickel Alloy, by Quenching.*

(In Percentages above the Results given by the Corresponding Metal before Quenching.)

	In Oil.		In Water.	
	Elastic Limit. Per cent.	Ultimate Strength. Per cent.	Elastic Limit. Per cent.	Ultimate Strength. Per cent.
Homogeneous iron, ...	50	15	31	4
Alloy containing 7.5 per cent. nickel, .	96	84	116	132

Nickel of itself can therefore confer upon its alloys with iron the property of taking increased strength by quenching. The higher nickel-alloys (over 16 per cent.) are not affected by heat-treatment. When, in connection with the properties due to nickel alone, the effect of the carbon present is considered, the extreme sensitiveness to heat-treatment of the ordinary grades of nickel-steels may be understood and appreciated.

Annealing-Temperature of Nickel-Steels.

If steel be allowed to cool gradually from the solidification-point, it will be noticed that the fall of temperature is at first regular; at a certain point the cooling ceases, and the metal for a time either remains at a constant heat or even shows an increase in temperature; below this point the metal cools regularly as before. This point where cooling is interrupted marks the temperature at which steel changes from the amorphous and plastic condition, in which it can be forged and welded, into the crystalline structure which it retains when cold. It marks the temperature at which the best results can be produced by quenching, and it marks also the temperature to be attained (and very slightly exceeded) in annealing. The larger

* Rudeloff, *Verein zur Beförd. des Gewerbfl.*, vii. and viii., 1898.

† "Le Ferro-Nickel," *Rev. Univ. des Mines*, vol. xxvii., 1894, p. 142. The table here given is not directly quoted, but formed by calculation from M. Moulan's results.

the proportion of carbon present, the lower is the recalescent point, and the narrower are the ranges of temperature within which the steel can be safely worked. A 1.50-carbon steel can be refined (*i.e.*, brought to its maximum strength and hardness) by quenching from a dark orange red. A steel of 1.00-carbon can safely be heated to a little brighter redness; and a 0.50-carbon steel will bear a bright orange heat, which would burn and destroy the texture of a harder steel.

"The presence of nickel causes steel to crystallize at a much lower temperature than it would otherwise." This statement, by Mr. Ellis,* managing director of John Brown & Co., of Sheffield, is explained by an examination of the recalescent point of nickel-steel. The determination of this point has been made by Messrs. Henry Souther and F. S. Flavel for the Pope Manufacturing Company, of Hartford, and is shown, in comparison with steels of 0.25 and 0.50 per cent. carbon, in the curve exhibited in Fig. 2. It appears that the recalescent point of 0.25-carbon steel is a little over 1600° F., while that of 0.50-carbon steel is between 1350° and 1400°, and that of 5 per cent. nickel-steel, with 0.25 carbon, is about 1080° F. The recalescent point of pure nickel is 1112° F.† This furnishes an explanation of the supersensitiveness of nickel-steel to heat-treatment. The proper annealing-temperature for the simple carbon steel is, according to Mr. Souther, a full red, while for nickel-steel the heat should not be over a cherry-red. (See Fig. 2.)

The Welding of Nickel-Steels.

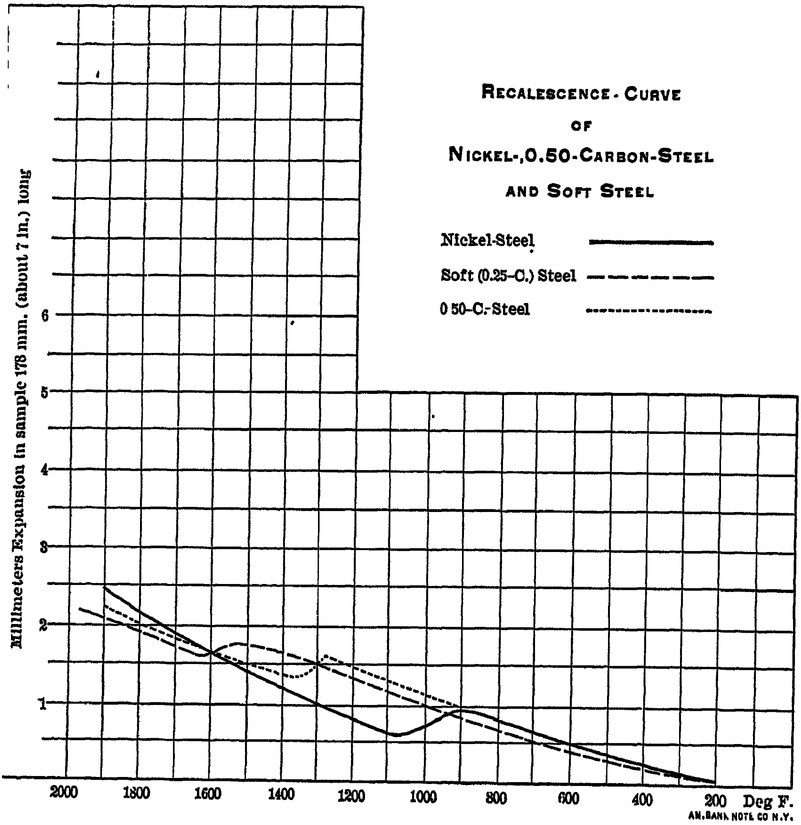
Nickel has a great affinity for oxygen, which renders the welding of high-nickel steels a matter of difficulty. Among steel-makers the term "welding" is often used to express the hammer-treatment of a cast ingot at a bright red heat to insure the absence of blow-holes and internal flaws or cracks. Among the steel-users, welding means exclusively the union by hammering or pressure of two pieces of steel at the proper temperature. All nickel-steels may be consolidated and forged into homogeneous masses under the hammer or hydraulic press. In other words, the presence of large amounts of nickel does not render

* "Recent Experiments in Armor," *Trans. Inst. Naval Architects*, March, 1894.

† "Nickel Extraction by the Mond Process," W. C. Roberts-Austen, *Proc. Inst. Civil Engrs.*, London, Nov., 1898, vol. cxxxv., p. 46.

steel red-short. For blacksmiths' work, however, an increase in the amount of carbon, or an increase in the amount of nickel, renders welding difficult. A perfectly welded union should be as strong at the points of contact as at any other part of the welded piece; and hence a job of welding which a blacksmith might deem satisfactory might not show good results in a testing-machine.

FIG. 2.



The writer has had the following tests made by a skillful, practical blacksmith:

(1) Steel, 2.05 Ni, 0.22 C, cut like soft steel; welded perfectly; no sign of weld showing; bent twice at right angles at the weld when hot; the weld did not open, nor was any crack noted; bent at right angles when cold; failed to show any crack at the weld.

(2) Samples containing 3.25 per cent. nickel and 0.16 carbon worked exactly like No. 1, under the same tests; no crack was developed, and the metal welded perfectly.

(3) Samples containing 3.40 per cent. nickel and 0.31 carbon cut a trifle harder, also hammered like a harder steel; welded perfectly; bent hot and cold, like No. 1, and showed no crack. The weld could not be seen.

(4) Samples containing 2.62 per cent. nickel and 0.19 carbon worked exactly like Nos. 1 and 2. The tests did not show any weakness at the weld.

(5) Samples containing 3.20 per cent. nickel and 0.54 carbon worked a little harder, but gave a perfectly solid weld. There were no cracks on bending, whether hot or cold.

(6) Samples containing 3.10 per cent. nickel and 0.96 carbon worked harder (*i.e.*, like a tool-steel); welded perfectly, and showed no cracks on bending hot or cold.

(7) Samples containing 4.95 per cent. nickel and 0.51 carbon worked like No. 5, but not as hard as No. 6. The weld was good, and no cracks developed on bending.

These tests are more practical than scientific. The writer has also seen an 18 per cent. nickel-steel split-welded to soft carbon-steel: the weld, ground down on an emery-wheel, showed apparently perfect union. Tests of the same metal for strength and elongation in welded and unwelded samples are likely to be deceptive, since the presence of nickel renders the carbon very sensitive to the heat-treatment received in welding, and, therefore, unless the welded and normal bars are subjected to the same annealing before testing, the results are discordant.

Mr. Hadfield, in his recent paper on the "Alloys of Iron and Nickel" (cited above), expresses the opinion that it is not possible to produce a perfect weld in nickel-iron alloys. Admitting that, with very high percentages of nickel, welding is impossible, I must, however, maintain that Mr. Hadfield's conclusions are not entirely corroborated by the experience of others. Some very interesting tests have been made by the Canadian Copper Co. on the loss of strength in welded specimens of nickel-steel. Two test-pieces of each grade were prepared; one was tested in its normal condition, while the other piece was cut in two, electrically welded, and then tested. The results are shown in Table XV. on page 592.

Tests made at the Royal Prussian Testing Institute show that the average tensile strength of welded bars of medium steel (no nickel) was 58 per cent. of that of the original bars before welding. In softer steels (no nickel) the average strength was 71 per cent., while in puddled iron the average was 81 per cent.

Beardmore* gives carefully-conducted welding-tests on 0.26-

* "Nickel-Steel as an Improved Material for Boiler Shell Plates, etc."

TABLE XV.—*Tests of Electrically-Welded Nickel-Steel.*

No.	Carbon. Per cent.	Nickel. Per cent.		Tensile Strength. Lbs per Sq In.	Elongation. Per cent.	Reduction of Area. Per cent.	Loss of Strength by Welding Per cent
13	0.22	2.05	Normal,	85,920	33	59	
			Welded,	80,360	17	25	5.3
14	0.16	3.35	Normal,	97,820	29	56	
			Welded,	87,500	6.9	7.5	10.5
19	0.19	2.62	Normal,	148,100	12.5	17.4	
			Welded,	117,800	1.7	1.7	20.4
24	0.54	3.00	Normal,	151,430	8.0	8.4	
			Welded,	117,600	2.3	1.7	22.3
29	0.96	3.10	Normal,	135,550	8.5	28.9	
			Welded,	114,600	4.6	4.5	15.4
41	0.51	4.93	Normal,	115,730	3.5	6.9	
			Welded,	104,050	3.4	2.9	10.0

carbon, 3 per cent. nickel-steels, the average of which is as follows:

	Ultimate Strength. Lbs. per Sq. In.	Elongation. Per cent.
Normal,	78,622	24
Welded,	78,904	16

These tests show the same strength, but a decrease in ductility after welding.

It may be taken as a rule, however, that steel containing over 3 per cent. of nickel is difficult to weld, the cause being the tenacity with which a film of oxide clings to nickel-steel. A good flux lessens, but does not entirely remove, this difficulty.

The Effect of Nickel on Hardness.

"You cannot make a very low-carbon steel hard by the addition of nickel alone." This opinion, expressed by Mr. Chase, of the Midvale Steel Co., is corroborated by others. Gun-barrels, containing 4.5 per cent. of nickel and 0.30 carbon, are soft and very ductile; the steel can be cut with a knife,* and yet tensile tests show an elastic limit of 80,000 pounds, with 105,000 pounds ultimate strength. The elongation is 25 per cent., and the reduction of area 45 to 50 per cent. This high tensile strength of 80,000 pounds could be attained in simple steel by the use of about 0.70 per cent. of carbon, but at the expense of a hardness and brittleness not shown by the nickel-

* Mr. Porter, Bethlehem Steel Co. Private communication.

steel. Nickel-steel rolls, containing 1 per cent. of carbon and 5 of nickel, made by the Reliance Steel Casting Co., "were certainly turned easier than 1 per cent. carbon simple steel."*

Mr. Hadfield says, in the paper already cited:

"While the samples (containing 11.39 and 15.48 per cent. of nickel) present extraordinarily high resistance to compression, they cannot be described as possessing hardness like that of carbon-steel in its hardened condition. . . . . It is doubtful whether any specimen of carbon-steel in its ordinary condition (that is, unhardened) has ever been known to give such a high tenacity, for example, as Specimen I. (0.18 carbon, 11.39 nickel), which, in the unannealed condition, possesses a tensile strength of 94 tons (210,560 pounds) per square inch. Yet these specimens, to the machine-tool or file, in no way compare with the hardness of carbon-steel."

The effect of nickel on hardening is not due to the influence of nickel alone, but to its effect on the carbon in rendering that element more sensitive to heat-treatment. If a steel contains less than 6 per cent. of nickel, the influence of the amount of carbon present on the hardness obtained by water-quenching is very strongly marked. Above 8 per cent. of nickel, the effect of the carbon present seems to be partially masked by the nickel; 18 per cent. nickel-steel is as hard and elastic with 0.30 as with 0.75 carbon. If steel containing 18 per cent. nickel and 0.60 carbon be heated and plunged into water, it will be perceptibly softened; and if the nickel be raised to 25 per cent., this softening is very noticeable.†

"At 20 per cent. of nickel," says Mr. Riley, "successive increments of nickel tend to make the steel softer and more ductile, and even to neutralize the influence of carbon."

An 18 per cent. nickel-steel, with 0.60 carbon, if heated to a good red heat and worked on the anvil until cold, will have the hardness and elasticity, without the brittleness, of a piece of tempered steel. The nickel-steel takes the temper and hardness by hammering alone—water-quenching will soften it. The 18 per cent. nickel-steel is exceedingly hard to punch cold; but, as the nickel increases, the steel softens, and a 25 per cent. nickel-steel can be worked cold almost as easily as German silver.‡ The explanation of this peculiar behavior may be

* Mr. Bailey, Reliance Steel Casting Co. Private communication.

† Mr. H. J. Williams, Damascus Steel Co. Private communication.

‡ Mr. H. J. Williams, Damascus Steel Co. Private communication.

found in the experiments made in Berlin by Prof. Rudeloff. On melting in crucibles a steel calculated to contain 1 per cent. of carbon and 30 of nickel, he found that 80 per cent. of the carbon present was found in the finished alloy as graphite. With a steel containing 1 per cent. of carbon and 60 of nickel, the same conditions were found to obtain.* This seems to indicate that in steels containing less than 6 per cent. of nickel the effect of nickel was to throw the carbon into a condition where it is exceedingly sensitive to heat-treatment; but as the percentage of nickel rises, the carbon is thrown more and more into the graphitic state, upon which heat-treatment does not produce any effect.

Rigidity of Nickel-Steels.

Under impact-tests, in which a heavy weight is allowed to fall upon a steel bar, supported at its extremities, nickel-steel with about 3 per cent. of nickel shows about 48 per cent. greater stiffness, and 45 per cent. greater toughness, than carbon-steel. The word *stiffness* refers here to the amount of deflection produced by the blow; while the word *toughness* refers to the number of blows required to produce rupture.

Beardmore says that, in experiments with nickel- and carbon-steel of the same carbon-contents, the nickel-steel was fractured at 7 impact-blows, and broke after 35 blows; while the simple steel was fractured at 5 and broke after only 12 blows.

Mr. Taylor, of the Carnegie Steel Co., has kindly furnished copies of impact-tests, made upon simple steel and nickel-steel axles. The weight dropped was 1640 pounds; but as the nickel-steel axles were ⅜ inches greater in diameter than those of simple steel, the momentum was made proportional by allowing a drop of 29 feet on the simple steel and of 44 feet on the nickel-steel. In Tables XVI. and XVII., representing these tests, it will be noted that the simple steel was deflected by the first blow 7.25 inches, and broke after 47 blows; while the nickel-steel was deflected only 5.0625 inches, and broke only after 68 blows.

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* *Verein zur Beförderung des Gewerbfleisses*, 1897, p. 242.

TABLE XVI.—*Record of Tests of Simple Steel Axles, $4\frac{3}{8}$ Inches in Diameter at the Center, by the Bureau of Inspection of the Carnegie Steel Co., Ltd.*

Heat. No.	Chemical Analysis. C. Per cent.	P. Per cent.	Mn. Per cent.	S. Per cent.	Physical Tests. Elastic Limit. Lbs. per Sq. In.	Tensile Strength. Lbs. per Sq. In.	Elongation in 2 In. Per cent.	Reduction of Area. Per cent.	Height of Drop. Feet.	Weight of Drop. Lbs.	Deflection after First Blow. In.	No. of Blow at which Axle Broke.	Reduced Diameter of Axle. In.	Remarks.
12,170	0.35	0.017	0.50	0.022	49,110	75,190	28.0	44.3	28	1,610	7¼	These axles received only 5 blows. No fracture.		These axles were tested on the solid-base machine. All smooth-forged.
11,273	0.35	0.010	0.41	0.023	47,270	71,060	25.0	42.2	"	"	6½			
12,161	0.40	0.031	0.50	0.031	48,660	71,510	30.0	50.2	"	"	7			
12,181	0.39	0.011	0.62	0.020	58,760	73,720	26.5	49.4	"	"	7¾			
12,180	0.37	0.010	0.43	0.021	54,350	72,980	25.0	50.2	"	"	7½			
11,189	0.36	0.015	0.66	0.022	48,280	76,530	27.0	47.7	"	"	7½			
12,179	0.35	0.013	0.45	0.022	60,680	71,620	27.0	44.2	"	"	7½			
12,269	0.37	0.018	0.45	0.022	44,050	70,610	27.0	42.8	"	"	6⅝			
15,046	0.24	0.039	0.42	0.033					29	"	7¼	48th	$4\frac{1}{16}$	Fracture granular. Drop-tests were made on the spring-base machine. These axles were forged from round blooms and re-annealed. No physical tests were made.
15,046	0.24	0.039	0.42	0.033					"	"	7⅜	52d	$4\frac{1}{16}$	
15,046	0.24	0.039	0.42	0.033					"	"	7½	41st	$4\frac{1}{8}$	
20,010	0.26	0.016	0.44	0.037					"	"	7½	44th	$4\frac{1}{16}$	
14,051	0.25	0.020	0.44	0.031					"	"	7½	50th	4	
14,051	0.25	0.020	0.44	0.031					"	"	7	47th	4	

TABLE. XVII.—*Record of Tests of Nickel-Steel Axles, $5\frac{3}{8}$ Inches in Diameter at the Center, and Tested to Destruction, by the Bureau of Inspection of the Carnegie Steel Co., Ltd.*

(Drop-Tests made on Spring-Base Machine. Height of Drop, 44 Feet; Weight, 1640 Pounds.)

Heat. No.	Chemical Analysis. C. Per cent.	P. Per cent.	Mn. Per cent.	S. Per cent.	Ni. Per cent.	Physical Tests. Elastic Limit. Lbs. per Sq. In.	Tensile Strg'h. Lbs. per Sq. In.	Elongation in 2 In. Per cent.	Reduction of Area. Per cent.	Deflection after First Blow. In.	No. of Blow at which Axle Started to Open.	No. of Blow at which Axle Broke.	Reduced Diameter of Axle. In.	Remarks. The fracture in all cases was fibrous and silky.
1,187	0.24	0.011	0.76	0.020	3.40	54,140	85,680	30.0	57.3	5	35th	62d	4½	Penetration 2 in. on one side; 1¾ on the other.
1,216	0.24	0.011	0.80	0.019	3.28	54,180	85,410	32.0	59.3	5	40th	79th	$4\frac{7}{16}$	" 2¼ " " " 2 " "
1,210	0.26	0.011	0.79	0.022	3.00	57,190	85,620	30.0	56.9	5⅛	30th	54th	4¾	" 3⅛ " " " 1¼ " "
1,208	0.22	0.010	0.72	0.019	3.30	55,000	82,760	33.0	57.7	5½	36th	68th	4½	" 1¾ " " " 2 " "
1,212	0.25	0.010	0.70	0.019	3.68	55,410	87,680	29.0	54.9	4¼	45th	78th	4⅝	" 2¼ " " " 1⅞ " "

The Effect of Nickel on Compressive Strength.

In an alloy of pure iron with varying percentages of nickel, the resistances to compression have been determined. Resistance to direct compression varies directly with the percentage of nickel in the alloy, up to 16 per cent., very nearly in the same manner as the resistance to tension, except that for tension the maximum strength is reached at 8, while the maximum for compression is reached at 16 per cent. In comparative tests, in which small blocks of the alloys were subjected to the blows of a heavy hammer, the same ratio between the nickel-contents and the resistance to compression was observed; and it was noted also that, up to 16 per cent. of nickel, the resistance of the block to compression increases with the number of blows given, and that this increased resistance is also in direct ratio to the amount of nickel, up to the maximum of 16 per cent. In other words, nickel seems to increase the gain in strength produced by cold-working.*

Mr. Hadfield has published the results of compression-tests on nickel-steels of low carbon.† He finds that samples containing 11.39 and 15.48 per cent. of nickel possess extraordinarily high compressive-strength. These samples showed a shortening of only 1 per cent. by a load of 100 tons; while, under the same conditions, a low-carbon steel, without nickel, was shortened 50 per cent.

TABLE XVIII.—*Compression-Tests by Mr. Hadfield.*

Mark of Test.	Carbon. Per cent.	Nickel. Per cent.	Elastic Limit by Compression. Tons per Sq. In.	Shortening by 100-Ton Load. Per cent.
a	.19	.27	22	50
b	.14	.51	22	50
c	.13	.95	20	49
d	.14	1.92	27	47
e	.19	3.82	28	41
f	.18	5.81	40	37
g	.17	7.65	40	33
h	.16	9.51	70	3
i	.18	11.39	100	1
j	.23	15.48	80	1
k	.19	19.64	80	3
l	.16	24.51	50	16
m	.14	29.07	24	41

* Rudeloff, *Verein zur Beförderung des Gewerbfleisses*, 1896.

† "Alloys of Iron and Nickel," *Proc. Inst. Civil Engrs.*, vol. cxxxviii, p. 22.

Mr. Hadfield, in the paper previously cited, says:

"Some noteworthy results are obtained, especially in samples i and j, in which the resistance to compression is extraordinarily high. These results are the more remarkable in view of the low carbon present. . . . A still more curious point is, that notwithstanding the high resistance to compression stresses, they are comparatively soft and can be machined—though not readily. . . . There is no doubt that as regards pure alloys of iron and nickel, that is, no carbon or other elements being present or to only a small extent, the increase in resistance to stress is a most remarkable property, apparently only possessed by these nickel-iron alloys."

The Shearing-Strength of Nickel-Steels.

In shearing the edges of rolled deck-plates, carbon-steel often cuts raggedly—small fragments breaking back from the edge of the shears. Nickel-steel, on the other hand, cuts clean, like a very mild steel.* This is also true of punching. "Careful experiments in punching show that the hole is left with clean-cut edges, with no slivers or wire-edges. Nickel-plates shear more neatly than carbon-plates."†

Prof. Rudeloff has investigated the influence of nickel upon the shearing-strength of iron, with the following results:‡

TABLE XIX.—*Effect of Nickel on Shearing-Strength.*

Nickel. Per cent.	Shearing-Strength. Lbs. per Sq. In.
0,	39,303
1.0,	40,441
2.0,	47,363
3.0,	47,363
4.0,	48,311
5.0,	52,009
8.0,	61,826
15.5,	95,581
30.0,	50,349
60.0,	53,905
93.0,	50,705
98.0,	49,306

The shearing-strength rapidly rises with increase in the percentage of nickel, up to 16 per cent., at which point the nickel-alloy has 2.5 times the shearing-strength of pure iron.

* E. F. Wood, Carnegie Steel Co. Private communication.

† "The Advantages of Nickel-Steel," Commander J. G. Eaton.

‡ M. Rudeloff, "Vierter Bericht des Sonderausschusses für Eisenlegirungen," *Verein zur Bef. des Gewerbfl.*, Berlin, 1896.

Further results on the shearing of nickel-steels are given below, under the head of nickel-steel rivets.

Loss of Strength on Punching.

Tests have been made at the Parkhead Forge rolling-mill, in Glasgow, Scotland, to determine the original strength of nickel-steel boiler-plates, and also the residual strength, after a portion had been removed by punching. Two samples of plate were tested: No. 1 being mild steel, of usual "boiler-plate" quality, and No. 2 a steel somewhat higher in carbon. Each contained the usual 3 per cent. of nickel. The tensile strength of the whole sheets, before punching, averaged as follows:

	Lbs. per Sq. In.
No. 1,	84,672
No. 2,	116,480

Test-pieces of these sheets, about 3.5 inches in width, were taken, and, in the center of each, 1-inch holes were punched. The samples were then subjected to tensile tests, with the following average results:

	Lbs. per Sq. In.
No. 1,	71,523
No. 2,	89,510

The loss of strength by punching was, for No. 1, 15.5 per cent., and for No. 2, 20 per cent. of the original strength. On the thicker sections of No. 1 the loss in strength was only about 10 per cent.

Mr. Beardmore states the loss of strength due to punching in ordinary mild steel to be 33 per cent. of the original strength.

This is, however, higher than is usually reported. Prof. Howe says that it ranges from 9 to 34 per cent.—the average of tests on simple-steel plates showing a little over 20 per cent. loss on punching.

It is evident from this comparison that nickel-steel suffers from punching at least as little as mild boiler-steel. Mr. Beardmore claims that in this regard nickel-steel is much superior to the simple steels.*

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* "Nickel Steel," *Inst. Engrs. and Shipbuilders of Scotland*, March, 1896; *Industries and Iron*, May, 1896.

The Influence of Nickel on Appearance and Tests.

In handling the charge in the open-hearth furnace, the melter relies for guidance upon the appearance of the fracture of small test-bars, taken from time to time. With simple carbon-steels, a very accurate estimate of the amount of carbon present can be thus obtained. Nickel changes entirely the characteristic appearance of the fracture. Test-bars from a heat of nickel-steel show very pronounced crystallization, like the chill of cast-iron, the crystals meeting sharply at the angles of the test-mould. Nickel-steel has a darker fracture than simple steel; and the furnace-man, judging by the appearance of the crystallization, would be apt to think the carbon was higher than is really the case. If, however, a series of test-bars be taken during a heat of nickel-steel, it will be found that the appearance changes regularly as the carbon drops; and the appearance of the fracture, once learned, forms as safe a criterion of the carbon-contents as is furnished by the corresponding changes in the case of simple steel.

In color-carbon tests on nickel-steels, the chemist is apt to estimate the carbon too low—not because of any color given by the nickel present (which, of itself, does not interfere with the color-test), but by reason of the effect of nickel on the carbon, changing part of it to the hardening-condition, in which form its color-effect is not so visible as that of cement-carbon.* For accurate comparison of tests, therefore, combustion-determinations of carbon are necessary.

The color of the finished steel becomes lighter with increase in the nickel-contents. The ordinary 3.5 per cent. nickel-steels do not perceptibly differ in appearance from simple steels; at 10 per cent. of nickel, the color is noticeably lighter; and, at 18 per cent., the steel has a soft silvery whiteness; with higher percentages the color seems again to darken, and the 25 and 30 per cent. nickel-steels are duller and less lustrous than the 18 per cent. In texture, moreover, the 18 per cent. nickel-steels appear more smooth and close-grained than iron-alloys containing a larger percentage of nickel.

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* Mr. Chase, Midvale Steel Works. Private communication.

Segregation in Nickel-Steel.

The various elements which enter into the composition of steels—silicon, sulphur, phosphorus, manganese and carbon—are all thoroughly mixed in the molten steel, and, in the furnace, are evenly distributed throughout the charge. When the steel is cast in the ingot-mould, each of these elements forming its own alloy with iron, and each solidifying at a different temperature and possessing a different specific gravity from the others, begins to move through the fluid steel. As the mass cools, the tendency of these compounds is towards the central and upper part of the ingot. Analysis shows that the center of an ingot contains a much greater proportion of carbon, silicon, sulphur and phosphorus than the outside; and for this reason, in the manufacture of shafting, gun-hoops and other articles in which uniformity of composition is a *sine qua non*, the center of the ingot is removed by boring.

"Nickel is supposed to lessen the segregation and liquation of carbon by combining with the carbon which cements the particles of iron together, and thus bringing the specific gravity of the carbon compounds nearer to that of the rest of the alloys in the fluid mixture. It also seems to cause this cementing carbon to solidify at more nearly the same temperature as the other alloys."*

Analyses from an ingot of uncompressed nickel-steel, 66.5 inches in diameter and 122 inches long, made by the Bethlehem Steel Co., gave the following result:†

TABLE XX.—*Segregation in Nickel-Steel.*

	Outside. Per cent.	Six In. from Center. Per cent.	Ratio of Concentration.
Nickel,	3.07	3.27	100 : 108
Silicon,	0.172	0.170	100 : 98
Sulphur,	0.03	0.06	100 : 200
Carbon,	0.31	0.36	100 : 116
Phosphorus,	0.025	0.047	100 : 188

It will be noted that in this nickel-steel ingot the segregation-excess of carbon is only 0.008 per cent. Prof. Howe in his *Metallurgy of Steel*, states that in simple steels the average segregation-excess of carbon is greater than that of any other element; and, in five cases which he cites, it exceeds 0.44 per cent.

* Mr. G. H. Chase, Midvale Steel Works. Private communication.

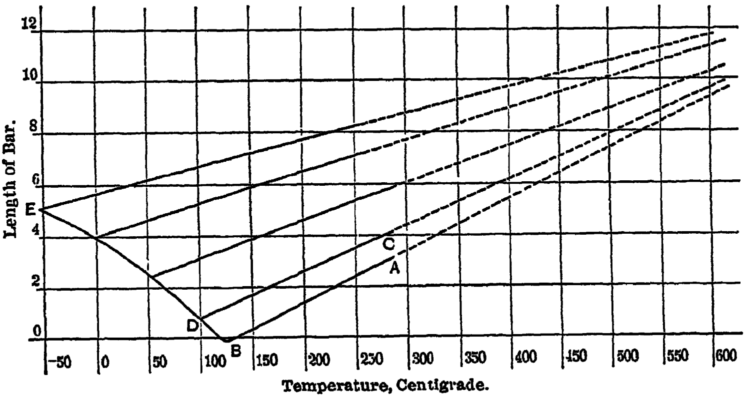
† Mr. H. F. J. Porter, Bethlehem Steel Works. Private communication.

Coefficient of Expansion.

Simple steel, when heated or cooled 1 degree Centigrade, at ordinary temperature, expands or contracts about 11.6 parts in a million. Expressed in the usual way, the coefficient of expansion of simple steel for each degree C. is 0.0000116.

According to M. Ch. Ed. Guillaume,* the coefficients of nickel-steels are normal up to 19 per cent. of nickel, from which point the coefficients rise rapidly up to 24 per cent., then fall to a minimum with steels containing 36 per cent. of nickel, and then, with further increase in nickel, return to a normal value. In investigating the behavior of these alloys, M. Guillaume discovered several remarkable anomalies which led him to divide

FIG. 3.



EXPANSION AND CONTRACTION OF 15 PER CENT NICKEL-STEEL
BY CH. ED. GUILLAUME.

nickel-steels into two classes: those containing less than 26 per cent. of nickel, which he calls *irreversible* alloys, and which show entirely different behavior at ascending and at descending temperatures; and those containing over 26 per cent. of nickel (the *reversible* alloys), which have a regular coefficient of expansion, the same for rising as for falling temperatures.

All the *irreversible* alloys show practically the same behavior as the 15 per cent. nickel-steel, as shown in Fig. 3, in which the abscissæ represent the temperature and the ordinates the length of the bar. When, after heating to cherry-red, the bar is allowed to cool, the metal contracts regularly, as shown by

* "Recherches sur les Aciers au Nickel," *Comptes Rendus*, March 7, 1898.

the line A B. At about 130° C., however, the bar commences to expand, and continues to expand as the temperature falls; and the rate of expansion on cooling is 40 parts in a million per degree C. If now, while the bar is cooling and expanding, it be taken (say at 100° C., when it has expanded to the point D) and reheated, it does not (as would be expected) contract till it reaches a temperature of 130°, and then expand, but expands immediately, along the line C D. On cooling, it contracts again along the line C D, and then expands along the line D E, continuing to expand as the temperature falls, until, at 60° below zero, C., the expansion is very slight. There are, for these "irreversible" alloys, two transformation-points; one near a red heat and the other at about 60° below zero, C. The more nickel contained in the steel (up to 26 per cent.), the lower the point (B) at which transformation by cooling commences; and the more rapidly is the point E attained, at which transformation is complete. The coefficient of expansion on heating from — 60° is 0.00001047, or 10.47 parts per million for each degree Centigrade.

The *reversible* nickel-steels (those containing over 26 per cent. of nickel) possess a regular coefficient of expansion, which varies according to the percentage of nickel. These coefficients, as given by M. Guillaume,* are as follows:

TABLE XXI.—*Coefficient of Expansion of Nickel-Steels.*

Nickel. Per cent.	Coefficients of Expansion between 0 and θ (in Centigrade Degrees).
26.2,	$(13.103 + 0.02123\,\theta)\ 10^{-6}$
27.9,	$(11.288 + 0.02889\,\theta)$ "
28.7,	$(10.387 + 0.03004\,\theta)$ "
30.4,	$(4.570 + 0.01194\,\theta)$ "
31.4,	$(3.395 + 0.00885\,\theta)$ "
34.6,	$(1.373 + 0.00237\,\theta)$ "
35.6,	$(0.877 + 0.00127\,\theta)$ "
37.3,	$(3.457 - 0.00647\,\theta)$ "
39.4,	$(5.357 - 0.00448\,\theta)$ "
44.4,	$(8.508 - 0.00251\,\theta)$ "
100.0,	$(12.514 + 0.00674\,\theta)$ "

The 26 per cent. nickel-steels expand a trifle more than pure nickel; then the coefficient of expansion rapidly decreases, reaching its minimum at 36 per cent. nickel, where the alloy

* *Journal de Physique*, 1898, troisiéme série, vol. vii., p. 266.

expands by heating only one-tenth as much as platinum and one-twentieth as much as brass.

Calculating from the above formula, it will be seen that for each degree Centigrade, nickel-steel of 36 per cent. nickel expands 0.878 parts in a million. Platinum expands 8.84, and brass 18.78 parts, under the same conditions.*

Density of Nickel-Steels.

The specific gravity of various nickel-iron alloys has been reported by various investigators as follows:

TABLE XXII.—*Specific Gravity of Nickel-Iron Alloys.*

Carbon.	Nickel. Per cent.	Character.	Density.	Observer.
Simple steel.....	0.		7.6 to 8.0	
Low-carbon......	3.0	Forged.	7.862	Beardmore.
0.19-carbon......	3.82	Cast.	7.777	Hadfield.
	5.0	Forged.	7.787	Guillaume.
0.17-carbon......	7.65	Cast.	7.743	Hadfield.
Low-carbon......	8.0	"	7.892	Rudeloff.
	10.0		7.866	Riley.
	15.	Forged.	7.903	Guillaume.
0.23-carbon......	15.48	Cast.	7.752	Hadfield.
	19.0	Forged.	7.913	Guillaume.
	24.0	(Magnetic.)	8.014	"
	24.	(Non-magnetic.)	8.111	"
0.16-carbon......	24.51	Cast.	7.810	Hadfield.
	26.		8.08	Riley.
	26.2	Forged.	8.096	Guillaume.
	29.	Wire.	8.4	Von Helmholz.
0.14-carbon......	29.07	Cast.	8.054	Hadfield.
	30.4	Forged.	8.049	Guillaume.
	31.4	"	8.008	"
	34.6		8.066	"
	37.2		8.005	"
	39.4		8.076	"
	44.3		8.120	"
	98.8	(Commercial Cast.)	8.839	Hadfield.
	98.8	" Forged.)	8.826	"
	98.8	" "	8.86	Riley.

Corrodibility of Nickel-Steel.

Nickel itself is very slightly affected by air, steam, moisture and acid vapors; in alloys with iron and steel, the incorrodibility increases with the percentage of nickel up to 18. "This alloy is practically non-corrodible. A sample hung for three months in the laboratory-fumes was very slightly corroded in spots, which seemed due to the condensation of acid in drops

* Thurston's *Materials of Engineering.*

on the surface."* Further increase in the percentage of nickel causes steel to become open-grained and not susceptible to tempering, and (probably for this reason) the 25 per cent. nickel-alloy will gather a faint coating of rust, where the 18 per cent. alloy would remain bright. "Tico" resistance-wire, containing 27.5 per cent. of nickel, was very slightly coated with rust after one year's exposure to water in a very wet cellar; iron wire, under the same conditions, was entirely changed to oxide. With the ordinary nickel-steels (3 to 3.5 per cent. nickel) corrosion is slightly less than in simple steels. Mr. Whyte, superintendent of Leith docks, has tested the loss in weight of nickel-steel, mild steel and wrought-iron, after twelve months' exposure to sea-water, with the following results:†

TABLE XXIII.—*Corrosion of Nickel-Steel, etc., by Sea-Water.*

	Loss in Weight. Per cent.
Planed nickel-steel (3 per cent. Ni),	1.36
" simple " (0.25 per cent. C),	1.72
" wrought-iron,	1.89
Unplaned nickel-steel,	0.74

Riley states that, as compared with 0.18 carbon-steel, the loss in weight by immersion in dilute hydrochloric acid was as follows:

TABLE XXIV.—*Corrosion of Nickel-Steel in Dilute Hydrochloric Acid.*

	Parts Actual Loss in Weight.
0.18-carbon steel,	1,000
5 per cent. nickel-steel,	830
25 " "	1.15

Wiggin gives the percentage of loss in steam and salt water as follows:

TABLE XXV.—*Corrosion of Nickel-Steel, etc., by Steam and Salt Water.*

	Loss by Boiling for 3 months in water with 10 Per cent. Salt. Per cent.	Loss by Treating with Steam for 2 months. Per cent.
Nickel-steel (3 per cent.),	1.00	.27
Bessemer steel,	1.81	.58
Open-hearth steel,	1.97	.31
" "	2.00	.36

* H. J. Williams, Damascus Tool-Steel Co., Pittsburgh.

† Beardmore, "Nickel-Steel as an Improved Material for Boiler-Plates."

Prof. Howe states that on exposure to fresh water and to air he has found the average loss in grammes as follows:*

TABLE XXVI.—*Loss of Weight of Nickel-Steel, etc., in Fresh Water and in Air.*

	Immersed in Fresh Water. Grammes.	Exposed to Air. Grammes.
High-nickel steel,	79	29
Low- "	251	61
Wrought-iron,	279	87
Soft steel,	274	117

Mr. Hadfield, experimenting on forged test-bars of nickel-steel containing about 0.20 per cent. of carbon, immersed for three weeks in 50 per cent. sulphuric acid, finds less difference in corrosion between nickel-steel and simple steel than is found by other investigators.

TABLE XXVII.—*Loss of Weight through Prolonged Immersion in Sulphuric Acid.*

Analysis.		
Carbon. Per cent.	Nickel. Per cent.	Loss. Per cent.
0.13	0.95	3.23
0.19	3.82	2.95
0.17	7.62	2.77
0.18	11.39	2.60
0.14	29.07	1.34

Experiments made by the writer seem to prove that the amount of carbon present has much influence on the corrodibility of nickel-steel. These tests were made by placing bars of the steel to be tested in a solution of 10 per cent. hydrochloric acid and 10 per cent. common salt in water. The samples were held apart by strips of wood, to avoid electrolytic action. The pickling was continued for a week; the samples were then carefully washed, brushed and weighed. The results are given in full in Table XXVIII. Arranging the samples into the three groups,—low, medium and high carbon,—it will be noted that in each group there is a fairly regular decrease in corrosion, corresponding to increase in nickel. Among special steels, that containing 18 per cent. of nickel gives remarkable results, showing a loss by corrosion of only 0.077 per cent., against a loss of 5.8 per cent. in low-carbon steel containing no nickel.

* See Appendix, page 647.

TABLE XXVIII.—*Corrosion-Tests of Nickel-Steels by Treatment with Hydrochloric Acid and Brine.*

Carbon. Per cent.	Nickel Per cent.	Loss. Per cent.
0.19	0.00	5.811
0.19	1.05	1.305
0.19	2.62	1.712
0.15	3.17	.664
0.16	3.55	.429
0.18	6.30	.547
0.33	0.00	2.121
0.37	1.05	1.287
0.29	1.90	.607
0.31	3.40	.434
0.31	3.75	.345
0.43	5.75	.318
0.73	0.00	1.508
0.81	1.15	.914
0.81	2.30	.924
0.91	3.10	.540
1.00	3.52	.483
.....	11.25	1.56
0.45	18.	.077
.....	23.86	.479
.....	99.8	.130

From the above tests it appears that, with steel of the same carbon-contents, corrosion decreases as nickel increases, while carbon itself, irrespective of the nickel present, seems also to increase the resistance to corrosion.

Electrical and Magnetic Qualities.

TABLE XXIX.—*Specific Resistance of Nickel-Steels.*

	Specific Resistance in Ohms per Meter 1mm. sq.	Authority.
Pure nickel, ...	0.126	Matthiessen.
Pure iron, ...	0.098	Matthiessen.
Nickel-steel, ...	0.80 to 0.90	Guillaume.
"Tico" wire, ...	0.810	Trenton Iron Co.
"Superior" wire, 86 microhms at 20° C.	0.860	Von Helmholz.
"Climax" wire, ...	0.784	Roebling.
German silver, ...	0.338	Von Helmholz.

According to Guillaume, all nickel-steels have a high electrical resistance which does not seem to vary very much with the percentage of nickel. The nickel-steel resistance-wires, "Tico," "Superior" and "Climax," containing from 25 to 30 per cent. of nickel, have about 48 times, while German silver has about 18 times, the resistance of copper.

Mr. Hadfield reports a very interesting series of tests of the electrical conductivity of nickel-steels, as follows:

TABLE XXX.—*Electrical Conductivity of Nickel-Steels.*

Analysis.		Condition of Material.	Comparative Electric Conductivity.	
Carbon. Per cent.	Nickel. Per cent.		Copper 100.	Iron 100.
0.14	1.92	Unannealed.	8.00	51.5
0.19	3.82	"	6.88	44.3
0.18	11.39	"	4.49	28.9
0.19	19.64	"	4.00	25.7
0.16	24.51	"	2.67	17.2
0.16	24.51	"	3.70	23.84
0.16	24.51	Water quenched.	3.02	19.45
......	31.00	Unannealed.	......	12.02

Hopkinson investigated, in 1890, the magnetic properties of nickel-steels. In examining a steel containing 4.7 per cent. of nickel and 0.22 of carbon, he found that on heating to 750° C. the steel became non-magnetic and absorbed considerable heat. On cooling to 632° C., this latent heat was given out and the metal again became magnetic. Nickel-steel with 24.5 per cent. of nickel was non-magnetic at ordinary temperatures, and remained non-magnetic up to 700° C. This material did not recalesce on cooling. If cooled down a little below the freezing-point, this steel became magnetic and remained so until heated up to 580° C. At this temperature it became non-magnetic, and remained so on cooling to the temperature of the air. From 4° C. to 580° C., this alloy can exist in two states: either magnetic or non-magnetic, according to the previous heat-treatment. The specific electrical resistance is .000052 in the magnetic and .000072 in the non-magnetic state.*

According to Guillaume, all nickel-steels below 25.7 per cent. Ni can be, at the same temperature, either magnetic or non-magnetic, according to their previous heat-treatment. These steels are comprised between the formulæ Fe and Fe_3Ni, and they show different properties at ascending and at descending temperatures.†

* Hopkinson, "Magnetic Properties of Alloys of Nickel and Iron," *Proc. Royal Soc.*, 1890, vol. xlviii., p. 1; *Engineering*, Sept. 5, 1890.

† "Recherches sur les Aciers au Nickel," *Comptes Rendus*, March, 1898.

When these nickel-steels, containing less than 25 per cent. Ni, are heated, they lose their magnetism at a point between dull and cherry-red. When they are cooled, they do not become magnetic until a temperature is reached much lower than that at which magnetism was lost. The return to the magnetic state is gradual; and the point at which magnetism is recovered is lower, in proportion, as the alloy is richer in nickel. For an alloy of 24 per cent., the return to the magnetic state occurs a little below zero. The alloys increase in volume on becoming magnetic, the density of the 24 per cent. nickel-steel being 8.111 in the non-magnetic, and 8.014 in the magnetic state. The temperature at which the loss of magnetism occurs can be represented as a function of the nickel present by the formula:

$$\theta = 34.1\,(n-26.7)-0.80\,(n-26.7)^2,$$

θ representing the temperature and n the percentage of nickel.

Steels containing more than 25 per cent. of nickel possess regular magnetic properties which depend on the actual, and not on the previous, temperature.

M. Marcel Déprez,* commenting on M. Guillaume's equation representing the loss of magnetism at given temperatures corresponding to the amount of nickel present, shows that for alloys with 26.7 per cent. the transformation takes place at 0° C.; while for 39.4 per cent. Ni, the temperature is 315°, and for 58 per cent. the highest value, 363° C., is attained. The transition from magnetic to non-magnetic condition takes place within a range of 50°. To eliminate the magnetism by means of boiling water, a 30 per cent. alloy is needed. This metal is strongly magnetic at 50° C.

The lower nickel-steels, containing 3 to 5 per cent. of nickel, possess a magnetic permeability greater than that of wrought-iron.

The magnetic saturation of simple steels and nickel-steels, at ordinary and at exceedingly low temperatures, has been investigated by Prof. Dewar. The method followed was to charge small magnets to saturation at the ordinary temperature, measure the deflection produced on a galvanometer, then plunge the

* *Rev. Générale des Sciences,* Feb. 15, 1898; *Jour. Iron and Steel Inst.,* No. 1, 1898, p. 506.

magnets into liquid air, whereby a temperature of —186° C. is attained, and note the magnetic strength again.

Simple steels behaved in the same general way; the first cooling diminished the magnetic moment 6 per cent., and on heating up to ordinary temperature, it was still further diminished about 16 per cent. On cooling again the magnetic moment increased 6 per cent., and from this point heating always diminished and cooling always increased the magnetic moment; so that at —186° C. the magnetism was 10 per cent. greater than at 5° C. The increase of magnetic moment, when cold, varies with the amount of carbon; hard steels showing 10, medium steels 20, and soft steels 30 per cent. increase on cooling.

With nickel-steels a different result was obtained. The steels containing 0.94, 3.82 and 7.65 per cent. of nickel all acted like high-carbon steels, the magnetic moment being 10 to 11 per cent. greater when cold than at ordinary temperatures. The alloy with 19.64 per cent. nickel showed a very considerable loss—nearly 50 per cent.—of magnetic moment on first cooling; on removal from the liquid air, the magnetism increased; and after that the magnetic moment was 25 per cent. smaller when cold than at ordinary temperatures.*

III.—Molecular Relation of Nickel to Iron and Carbon in Nickel-Steels.

It seems to be a generally accepted opinion that the effect of nickel in nickel-steels is two-fold:

1. With low-carbon, or nearly pure wrought-iron, nickel seems to form a homogeneous alloy, much tougher and stronger than either pure nickel or pure iron. This conclusion is strengthened by the experiments of M. Moulan, referred to on page 583, and by the experiments of Rudeloff, on page 574, of this paper.

2. It is well known that pure nickel and iron unite to form definite crystalline compounds. Such an alloy, containing iron 45.64, nickel 54.36, and corresponding to the formula Fe_8Ni_9, was discovered by the writer in nickel-matte and described in

* Dewar and Fleming on "Changes Produced in Magnetized Iron and Steels by Cooling to the Temperature of Liquid Air," *Proc. Royal Soc.*, May 21, 1896, vol. lx., p. 57.

the *Journal of Analytical and Applied Chemistry*, March, 1892. It occurs in the shape of thin, flat crystals, looking like corner-clippings of tin foil, and having the form of right-angled isosceles triangles, measuring at the most one-half inch on the longer side. The crystals are silver-white, exceedingly tough, flexible and malleable, and strongly magnetic. As far as can be judged they are as soft as pure iron, if not softer.

M. Guillaume, in his researches on the magnetic properties and expansion-coefficients of nickel-steels, finds that the most pronounced results and most remarkable peculiarities are shown by the alloys which correspond most closely to the formulæ Fe_2Ni and Fe_3Ni.

It would seem from this that nickel forms with iron a series of crystalline chemical compounds, which, from the experiments of Moulan and Rudeloff, would seem to be tougher and stronger than pure iron.

Assuming that, as many hold, nickel causes carbon to pass from the cement- to the hardening-condition, we may conceive that the stiffness and rigidity of nickel-steels are due to the effect of carbon in this condition; while the ductility of nickel-steel is due to the fact that the matrix (the nickel-iron "mineral") is tougher than simple iron, and permits more molecular distortion before breaking.

If we consider the effect of nickel in Harveyized armor-plate we see that in the unhardened under-part of the plate the nickel-iron alloy is soft, tough and ductile; while in the hardened surface the high-carbon nickel-steel is stiff, rigid and hard. Owing to the toughness of the back, a blow on the face is absorbed and its momentum used up in heating the whole plate, while in the case of simple steel a blow expends its momentum in local shattering of the surface. We consider, therefore, that the benefits arising from the use of nickel in armor are two-fold: it forms on the surface a hard, impenetrable carbon-alloy, back of which, and supporting it, is a soft, ductile, homogeneous base. We may conceive of the action of nickel in nickel-steel in much the same way, and consider the stiffness and rigidity of the metal as due to the combination of iron with carbon in the hardening condition, and the ductility of nickel-steel as due to the toughness and strength of the original matrix or crystalline compound of nickel and iron.

As previously stated, small amounts of nickel seem to throw carbon into the hardening-condition, and large amounts seem to cause the separation of carbon as graphite. The effect of nickel on carbon is well brought out by melting nickel with pig-iron. Dr. S. H. Emmens found that gray pig-iron, melted with 10 per cent. of nickel under charcoal, gave an intensely hard alloy, which could not be machined, but which was nevertheless gray, crystalline in fracture, and very strong. Mr. L. Dunham, Supt. of the Ashland furnaces, states that he has mixed nickel with cast-iron and finds that it will turn white iron to gray.

Some experiments made for the Canadian Copper Co. by Mr. Crowell, of Cleveland, confirm these statements. No. 2 charcoal pig-iron was melted, with varying amounts of nickel, and cast in sand-moulds into bars 1 inch square by 1 foot long. These bars were tested by transverse strain, being supported on bearings 7 inches apart. Four bars of pig-iron, free from nickel, broke under an average load of 4530 pounds. Iron, alloyed with 0.75 per cent. of nickel, showed a strength of 4400 pounds. One per cent. of nickel gave 4175 pounds; 2 per cent., 4800 pounds, and 3 per cent. 5200 pounds, as breaking-load. The fractures were all of good gray surface. The gain of strength due to 3 per cent. of nickel was only 12 per cent. To test the effect on chill, two castings were made in sand-moulds having one steel face; one casting of No. 2 pig-iron was chilled white throughout, while the other casting, of the same pig-iron with 1 per cent. of nickel, was chilled only one-third; indicating that nickel has a retarding effect on the chill.

It is somewhat curious that the presence of less than 1 per cent. of nickel, whether in pure iron, steel or cast-iron, seems to produce a detrimental effect. In all of Rudeloff's experiments, the alloys with 0.5 per cent. of nickel, whether tested by tension or compression, were decidedly lower in elastic limit and ultimate strength than pure iron. In Mr. Hadfield's experiments, low-carbon nickel-alloys with 0.5 per cent. of nickel show a perceptible loss of strength. In a series of experiments made by the Canadian Copper Co. it was noticed that alloys with less than 1 per cent. of nickel were decidedly weaker than the same steel without nickel; and the only plausible explanation was that in small amounts, under 1 per cent., nickel

seemed to be a foreign element, producing weakness; while in larger amounts, over 2 per cent., it seemed to unite with the steel and form a tough, homogeneous alloy.

IV.—Uses of Nickel-Steel.

The greater portion of the nickel-steel produced at the present time contains from 0.20 to 0.40 carbon and from 3 to 5 per cent. nickel. As this metal retains all the ductility of a low-carbon, and attains at the same time the strength and stiffness of a high-carbon steel, it has found a great variety of uses. In the following pages the opinions of steel-makers and steel-users, in regard to the application of nickel-steel to various purposes, will be given, as nearly as possible, in their own words.

Boilers.

Mr. Wm. Beardmore, speaking before the Institute of Engineers and Shipbuilders of Scotland, in 1896, said:

"With the growing demand for ships to attain a speed of 30 knots, boilers to work at higher pressure, greater strength with lighter section, it would seem as if a better iron were needed to supply the latest wants of engineers and shipbuilders. We require a metal which can be worked without any special care on the part of the artisan; a metal which in ship-building will enable us to reduce the scantlings, take from the weight of the boilers and add to the strength and reliableness of the propeller shafts. Nickel-steel fulfills all these conditions, and is, in my opinion, a most suitable metal with which to meet the demands for a metal stronger than steel. In nickel steel of .26 carbon we have a metal whose elastic limit is equal to the ultimate strength of ordinary carbon steel. Mild nickel-steel gives all the properties of high-carbon metal, without the treacherous brittleness so painfully evident in the latter."*

At the Cleveland Rolling Mill Co. the effect of 2.7 per cent. of nickel in flange-steel of 0.10 carbon was tested; the two metals, practically identical except as to nickel, gave the following average results:

	Elastic Limit. Lbs. per Sq. In.	Ultimate Strength. Lbs. per Sq. In.	Elongation. Per cent.	Reduction of Area. Per cent.
Flange-steel, 0.10 C., . . .	35,000	54,000	27.4	54
" " 0.08 C., 2.69 Ni.,	47,000	65,700	24.7	52

The addition of 2.69 per cent. of nickel to this grade of steel increased the elastic limit 31 per cent. and the ultimate strength

* Beardmore, *Industries and Iron*, May, 1896. See, also, *Proc. Inst. of Nav. Architects*, April, 1897, vol. xxxviii., p. 274.

20 per cent., while the ductility (as shown by elongation) is nearly the same in both steels.*

Experiments in flanging nickel-steel plates of every thickness suitable for boilers show that this material is worked without any difficulty; it can be readily forged and pressed into dies, without cracking, and its large elongation enables it to be worked to great advantage.† Comparative tests of boiler-plate for the United States vessel Chicago, with a boiler-plate made from the same metal without nickel, gave the following results:

	Elastic Limit. Lbs. per Sq. In.	Ultimate Strength. Lbs. per Sq. In.	Elongation Per cent.	Reduction of Area. Per cent.
Nickel-steel boiler-plate, .	61,830	87,380	21.7	52.2
Carbon-steel, . . .	31,840	60,650	27.0	49.5

Mr. Landis says that when the boiler is made entirely of nickel-steel, thus preventing electrolytic action, there is no doubt but that it is the best material yet applied to this purpose.‡

Shafts.

Owing to the great length and high speed of modern steamships, it is necessary to make use of exceedingly high-grade material in crank- and connecting-shafts.

The U. S. government requires that shafts for the navy be hollow; and this custom is being rapidly taken up in general marine practice. A hollow-forged oil-tempered nickel-steel shaft has been made for the United States battleship Brooklyn: outside diameter, 17½ inches; inside, 11 inches; length, 38 feet 11⅜ inches; weight, 19,112 pounds. Test-bars cut from this shaft gave a tensile strength of 94,245 pounds per square inch; elastic limit, 60,770 pounds; elongation, 25.55 per cent.; and reduction of area, 60.58 per cent.

Prof. Merriman is quoted in a paper read before the Society of Naval Architects and Marine Engineers, in 1893, by R. W. Davenport, as estimating the strength of these shafts, compared to solid shafts, when strained to one-half of their elastic limit, as follows:

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* Sperry, "Nickel and Nickel-Steel," *Trans. A. I. M. E.*, xxv., 63 (March 1895).

† H. A. Wiggin, *Jour. Iron and Steel Inst.*, 1895, No. 2, p. 166.

‡ "Nickel-Steel," *Scientific American*, Jan. 9, 1897.

Propeller shaft, United States battleship Brooklyn, nickel-steel:
(a) Horse-power transmitted, at 50 revolutions per minute, 15,780.
(b) Load, in pounds, at middle of a span of 12 feet on two supports, 276,280.

Simple-steel shaft, solid, 13 inches in diameter (same weight as above):
(a) Horse-power, transmitted under similar conditions, 5130.
(b) Load, in pounds, under similar conditions, 89,000; comparative strength, 3 to 1.

"A solid shaft of simple steel of the same strength as the nickel-steel shaft would be 18.9 inches diameter and weigh 53 per cent. more."*

The shafting for the battleship Iowa is of nickel-steel containing 0.27 carbon and 3.19 nickel. An average of 48 bars cut from this shaft gave the following tests:

Elastic Limit. Lbs. per Sq. In.	Ultimate Strength. Lbs. per Sq. In.	Elongation. Per cent.	Reduction of Area. Per cent.
60,000	94,500	24.6	59.5

The great gain in elastic limit permits reduction in section, with consequent saving of weight in heavy moving parts of high-speed engines.†

The American liner Paris has had constructed for her a spare length of shafting of nickel-steel, which has a tensile strength of 90,000 pounds per square inch, probably 25,000 pounds more than any British or German shaft.‡

The nickel-steel shaft for the North German Lloyd steamer Kaiser Wilhelm der Grosse weighs 83.3 metric tons (183,593 pounds), is 45 feet 9½ inches long, and shows a tensile strength of 39.4 tons (88,256 pounds), with 20 per cent. elongation.§

Mr. Beardmore‖ points out that a very striking feature of nickel-steel is, that a crack appearing in it will not develop, as in carbon-steel. One of the most frequent causes of casualties at sea, he says, is the breaking of propeller-shafts, due to the development of some flaw in the shaft. Having a number of bars made, 1½ inches square by 18 inches long, of nickel-steel and of ordinary steel, of the same carbon-content, he subjected them to the usual fatigue-tests. The carbon-steel was fractured

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* "Fatigue of Metal," H. F. J. Porter, *Jour. Frank. Inst.*, vol. cxlv., pp. 341, 342.

† "The Advantages of Nickel-Steel over Carbon-Steels," Commander J. G. Eaton, U. S. N.

‡ *The Steamship*, June, 1894.

§ *Stahl und Eisen.*, vol. xvii., pp. 484–485.

‖ Beardmore, *Trans. Inst. Nav. Arch.*, April, 1897.

after 5 blows and broke after 12 blows, while it required 7 blows to fracture the nickel-steel and 35 blows to break it. He says that nickel-steel tears gradually, while carbon-steel, once cracked, breaks short, and adds that, in his opinion, if propeller-shafts were made of nickel-steel, the question of failures would seldom or never be raised, for the reason that, should a crack appear at all in nickel-steel, it will not develop as it would in ordinary carbon-steel.

Engine-Forgings.

In discussing recent improvements in the manufacture of engine-forgings Mr. Davenport said, in 1893:*

"In the highest development of the modern marine engine, reduction of weight of all parts is of prime importance. A very pronounced improvement in strength and toughness can be obtained by the use of nickel-steel. The use of nickel allows a reduction of carbon, makes the steel more sensitive to temper, and facilitates the tempering of irregular shapes. In cases where, owing to thickness of sections and irregular shapes, tempering is not advisable, nickel-steel will show a higher combination of elasticity and toughness than any other material known."

This opinion was corroborated in 1897 by the *Railroad Gazette*, which said:†

"It is conceded by the best authorities that from nickel-steel, properly worked, forgings of such parts (locomotive cross-head pins, crank-pins, piston-rods and driving-axles) can now be made which greatly excel similar forgings of all other materials in elastic strength and toughness."

Mr. Porter, of the Bethlehem Iron Company, discussing this topic before the Western Society of Engineers, observed:‡

"Breakages of crank-pins and piston-rods of locomotives have caused mechanical men to seek a metal of high elastic limit and elongation which will successfully resist the severe alternating stresses to which they are subjected. . . . . Mild steel for connecting-rods should contain 0.20 to 0.25 carbon, and show, in specimens four diameters in length, a tensile strength of not less than 57,000 pounds per square inch, and an elastic limit of not less than 27,000 pounds, with an average elongation of 25 per cent.

"For the general run of engine-forgings, where little machine work is required, it is advisable to use a higher-carbon steel, with a tensile strength of about 75,000 pounds per square inch and an elastic limit of 35,000 pounds per square inch, together with an average elongation of 20 per cent. in four diameters.

"For such parts as crank-pins, cross-head pins and parts of machinery subject to severe alternating stresses and wearing action, a still higher grade of steel is

* R. W. Davenport, *Trans. Soc. Nav. Arch. and Marine Engineers.*

† *Railroad Gazette*, December 17, 1897.

‡ H. F. J. Porter, *Jour. Western Soc. of Engrs.*, October 7, 1896, vol. i., p. 736; *Railroad Gazette*, October, 1896.

recommended. Such steel should have a tensile strength of about 85,000 pounds, an elastic limit of about 40,000 pounds per square inch, and an elongation of 15 per cent. in four diameters. If such forgings are tempered, the tensile strength will become about 85,000 to 90,000 pounds per square inch; elastic limit, 45,000 to 55,000 pounds per square inch, and elongation 15 to 20 per cent. By introducing about 3 per cent. of nickel into steel, a finely-granular condition results and a high quality of steel is obtained. By hollow-forging nickel-steel, a material is obtained excelling all others known in elastic strength and toughness. Such forgings were used for the crank-pins, cross-head pins and axles of the new Purdue locomotive, Schenectady No. 2, while the piston-rods were of the same material, but forged solid. Test-bars of this material, ½-inch in diameter and 2 inches between measuring points, showed the following physical characteristics:

TABLE XXXI.—*Test of Nickel-Steel Forgings.*

Oil-Tempered, Annealed Nickel-Steel.	0.25 C., 3.5 Ni. Pounds per Square Inch.
Tensile strength,	91,000
Elastic limit,	57,000
	Per cent.
Proportion elastic to tensile,	62.4
Elongation,	25.05
Contraction,	56.45

"If we represent the strength of a solid wrought-iron shaft 14 inches in diameter and 30 feet in length, as shown in the upper figure, by the figure 1, a solid steel shaft of the same dimensions would be represented by the figures 1.29; if we were to make it of nickel-steel, its strength would be represented by 2.6. Now, if we were to take the same iron shaft and simply bore and anneal it, putting a 3½-inch hole through it, its strength would be represented by 1, just the same as the upper shaft; if we subsequently oil-temper it, its strength would be 1.89. A hollow forged-steel shaft of the same weight as the first, but of 22-inch outside diameter, with a 17-inch hole through it, would be represented by the figure 4; if oil-tempered, 5½; if made of nickel-steel, its strength would be represented by the figure 6, and if oil-tempered, by the figure 8."*

Speaking of the use of nickel-steel shafting in torpedo-boats, where reduction of weight is demanded, Mr. Davenport says:†

"The possible reduction in the weight of shafting for torpedo-boats by the use of steel of high elastic limit is exemplified in the case of the shafting made by the Bethlehem Iron Co. for the Herreshoff Manufacturing Co., to be used in Torpedo Boats 6 and 7. The first inquiry called for solid shafts, about 6 inches diameter, of 80,000 pounds tensile strength and 26 per cent. elongation in 2 inches by ½ inch diameter. To meet these requirements it was proposed to use nickel-steel annealed, but not tempered, of which the elastic limit would be about 50,000 pounds per square inch. It was pointed out by the manufacturers that if the shafts were bored and tempered, an elastic limit of 65,000 pounds, with an elongation of 22 per cent., could be guaranteed, and that if the elastic limit were

* H. F. J. Porter, "Fatigue of Metal," *Jour. Frank. Inst.*, vol. cxlv., p. 343.
† "Steel for Marine Engine-Forgings," *Cassier's Mag.*, August, 1897, p. 529.

raised from 50,000 to 65,000 pounds, a hole 4.16 inches in diameter could be bored through a shaft 6 inches in diameter, by which its weight would be reduced one-half without reducing its torsional strength.

"The shafts were made of nickel-steel, 6 inches in outside and 4 inches inside diameter, tempered and closed in at both ends. The average physical qualities shown by official specimens cut from these shafts were:

Tensile Strength. Pounds.	Elastic Limit. Pounds.	Elongation. Per cent.
101,000	68,700	22.12."

The alternating stresses to which the moving parts of engines are subjected, stresses much short of the elastic limit of the metal, will in time cause a molecular fatigue which gives rise to rupture. On this point Mr. H. K. Landis says:

"Where a steel of 0.20 per cent. carbon will withstand 300,000 double stresses on an alternate stress machine, a 0.50 carbon-steel will probably break at 400,000, and nickel-steel at 1,500,000 to 2,000,000 such double stresses, each stress being two thirds of its ultimate strength or very near its elastic limit."*

In complicated engine-forgings it frequently happens that, owing to the shape or size of the article, oil-tempering is impracticable. With reference to such contingencies, Mr. Colby† observes that in cases where oil-tempering is not practicable and special requirements are demanded, they can be obtained by using a somewhat softer and tougher steel, and the introduction of from 3 to 4 per cent. of nickel.

In the same connection the observation of Mr. Hadfield is of interest, that the addition of nickel, either by conferring greater homogeneity, or by some particular combination with the iron or carbon present, or both, appears to confer properties upon the alloy equivalent to an annealing; or, if annealing be employed, to reduce the stress produced by forging; it does this without injury or seriously lowering the elastic limit.

These reasons have led to the adoption, by a number of railways, of nickel-steel for piston-rods, crank-pins and other moving parts of engines which are subjected to severe strains. On this subject Mr. J. E. Johnson, of Longdale, Va., in a paper read before the American Society of Mechanical Engineers,‡ relates the experience of the Longdale Iron Co. with piston-

* H. K. Landis, *Scientific American*, January 9, 1897.

† A. L. Colby, "High-Carbon Steel for Forgings," *Eng. Club of Phila.*, Nov., 1896.

‡ *Trans. Am. Soc. Mech. Engrs.*, vol. xix., p. 700.

rods in Baldwin locomotives. Two piston-rods of ordinary machine-steel, after about fourteen months' service, broke and smashed the cylinder-heads. Soft Swedish iron was then tried, and after four months' service one of these broke in the same way. The breaking of the rod of soft material was not very surprising, and was met by ordering material for a set of rods of high-carbon and one of nickel-steel. These have been in use over two years and have given perfect satisfaction.

Railway-Axles.

The rigidity and elasticity which nickel-steel manifests under drop-tests, and which have been examined under the head of the rigidity of nickel-steel, have led to its use in railway locomotive- and car-axles. Over 600 freight-cars of 100,000 pounds capacity, for the Pittsburgh, Bessemer and Lake Erie railway, have been equipped by the Carnegie Steel Co. with axles of nickel-steel. Of the tests of these axles, shown in Table XVII., Mr. Wood says:*

"When carbon-steel breaks under the falling hammer, it breaks short and goes 'all at once.' Nickel-steel shows much greater rigidity than carbon-steel; and when it does break, it yields by a gradual cracking-in from the opposite sides.

"Nickel-steel gives warning; carbon steel does not. Axles of 0.25 carbon and 3 to 3.25 per cent. nickel are as stiff as 0.40 to 0.45 carbon; that is to say, the amount of deflection produced by the blow of the falling weight is about the same in a 0.25-carbon nickel-steel as in a 0.40 to 0.45-carbon simple steel, while the nickel-steel is much tougher and will withstand 50 per cent. more blows."

Railway-Tires.

When a locomotive at full speed strikes a curve, the safety of the train depends upon the resistance of the tire-flanges on the rails to the tangential force, which, if unchecked, would carry the locomotive forward in a straight line. It is customary in England to use low-carbon, and in the United States to use high-carbon steel for railway-tires. In either case the very best material obtainable (that which shows the greatest resistance to strain, combined with the power of resisting a sudden shock) is emphatically necessary.

"The usual specifications for railway-tires," says Mr. Beardmore, "demand that they shall stand compression one-sixth of their diameter without cracking.

* Mr. E. F. Wood, Carnegie Steel Co. Private communication.

"From a number of nickel-steel tires made at the Parkhead Forge, in Glasgow, one containing 0.18 carbon and 3 per cent. nickel gave the following physical tests:

TABLE XXXII.—*Test of Nickel-Steel Tire.*

Elastic limit, ...	55,000 lbs. per sq. in.
Ultimate strength, ...	87,000 " "
Elongation, ...	28.7 per cent.
Contraction, ...	46 "

"This tire, 39½ inches in diameter, was pressed down to 19 inches (three times what the specifications demanded) without showing signs of fracture. These results could not have been obtained from any other metal of 0.18-carbon known to me."*

Hull-Plates.

The collision or grounding of steel vessels brings an enormous and suddenly-applied force to bear upon a small area, the effect being similar to the blow of an armor-piercing shell. Under such circumstances the brittleness of carbon-steel offers much contrast to the toughness of nickel-steel. Says Commander Eaton:†

"A comparative test between a nickel-steel plate and a carbon-steel plate, made with a view to subjecting them to the same strains as those experienced by vessels grounding, disclosed the fact that nickel-steel was far better adapted for plating and frames than ordinary steel. . . . Both plates were riveted to angles in a manner intended to imitate the riveting of a ship's plate between the frames. A round-faced punch, placed on each plate, was then struck by a heavy falling weight. The diameter of the punch was 3 inches, and the head was carefully rounded to preclude cutting edges. Each plate endured 13 blows before rupture; but at the next blow each plate showed a clean aperture; that in the carbon plate was 23.1 square inches in the clear, while the aperture in the nickel plate was but three-quarters of a square inch.

"If these holes had been opened in a ship's bottom, at a depth of 25 feet, the rates of inflow would have been 11 tons per minute in the carbon plate, and 0 36 ton in the nickel plate. It would seem that comment on these figures is unnecessary. It should be stated that neither plate was annealed, an omission which counted more heavily against the nickel than against its compĕtitor. The nickel plate preserved its shape, and in a remarkable degree absorbed the energy of the blows without transmitting wrecking-strains to the angles. The carbon plate was twisted and bulged, and the angles holding it were bent so badly that the whole structure was on the point of being wrecked."

* Wm. Beardmore, "Nickel-Steel, etc.," *Inst. Naval Arch.*, April, 1897.

† "The Advantages of Nickel-Steel Over Carbon-Steels." See Bibliography at the end of this paper, page 645.

The fact that loss by corrosion of nickel-steel in salt and in fresh water is much less than carbon-steel* constitutes an additional factor in its fitness for hull-plates.

In nickel-steel for the hull-plates of vessels a tensile strength of 85,000 pounds, with an elastic limit of 60,000 pounds, has been obtained, together with an elongation of 20 per cent. Similar plates of ordinary steel would have a tensile strength but little over the elastic limit of nickel-steel, with an elastic limit about one-half that of nickel-steel.† In the case of steamships, the saving of weight that could be effected by the use of nickel-steel, and the increased capacity for coal or freight thereby attained, would increase greatly the earning power of the invested capital.

The British Admiralty requirements for ships' plates are from 26 to 30 tons (58,240 to 67,200 pounds) tensile strength. Nickel-steel (about 3 per cent. Ni) gives 52 tons (116,480 pounds) tensile strength, and the *yield-point* is 28 to 30 tons (62,720 to 67,200 pounds), equal to the *ultimate* tensile strength required by the Admiralty.‡

Armor-Plate.

The adoption by the United States government of nickel-steel as a material for armor-plate dates from the tests made at Annapolis, in 1890, of simple carbon-steel plates, compound plates of steel and wrought-iron, and unhardened nickel-steel plates. The results of these trials are too well known to need further comment. The resistance obtained with the nickel-steel plate far exceeded the expectations. At the fifth shot, with a striking energy of 4988 foot-tons, an 8-inch armor-piercing projectile broke in many pieces, after having forced its point but 10½ inches beyond the back, and without developing a sign of a crack. Never before in the history of modern armor had a plate given results to compare with these, withstanding a total energy of 16,940 foot-tons,—1835 foot-tons per ton of plate—without developing a single crack, and without being perforated.§

* See page 606.

† "Nickel-Steel, etc," H. A. Wiggin, *Iron and Steel Inst.*, 1895, No. 2, pp. 167, 168.

‡ "On Nickel-Steel," Wm. Beardmore, *Inst. Engrs. and Shipbuilders of Scotland*, March, 1896.

§ "The Year's Naval Progress," July, 1891. *Proc. United States Naval Inst. Jour. Franklin Inst.* Also, Report of Secretary of United States Navy; and F. L.

These results proved, beyond question, the superiority of nickel-steel as a material for armor-plate, and led to the decision of the Armor Board to use nickel-steel armor for the new battle-ships and cruisers of the United States navy. The average composition of the steel used is 3.25 per cent. nickel and 0.25 carbon. This forms an exceedingly tough and homogeneous metal, in which hardness is afterwards produced by the Harvey process of carburization. The finished armor-plate contains on the exterior face, about 1 per cent. carbon, which gradually diminishes until, at a depth of 2.5 inches, the original composition of 0.25 carbon is found. This plate can now be oil-tempered, annealed or subjected to any other heat-treatment desired. Admiral Sampson, speaking of the use of nickel in armor-plate, says:*

"To any metallurgist acquainted with the infinitude of results that may be obtained by a variation in the composition and treatment of simple steel, the advantageous possibilities arising from the introduction of so benign an ingredient as nickel must be apparent. In other words, where simple steel is strong and tough, both qualities may be improved by adding the proper amount of nickel. The susceptibility of nickel-steel to treatment is remarkable, and yet this steel may be abused in the most shameful way without failure. Nickel appears to render the carbon more sensitive to hardening, and hence water-hardened Harvey plates of nickel-steel are toughened at depths hardly affected in simple steel plates."

The adoption of nickel-steel as material for armor-plate by the United States government has led to its use by all the great powers; and at the present time nickel-steel is used, either in part or exclusively, as material for armor-plate and protective deck-coating in nearly all modern war-vessels, wherever constructed.

Structural Beams and Shapes.

Mr. H. H. Campbell† observes that the strength of a bridge of a given weight and design, the weight of a bridge of a given strength and design, and the longest span possible under a given design are all limited by the elastic strength of the mate-

Garrison, "Development of American Armor-Plate," *Jour. Franklin Inst.*, June, 1892, vol. cxxxiii., p. 426.

* "The Present Status of Face-Hardened Armor-Plate," *Soc. Nav. Arch. and Mar. Eng.*, 1894.

† *Trans. Am. Soc. Civ. Engrs.*, June, 1895, vol. xxxiv., p. 285.

rial used. These well-understood axioms point naturally to the use of steel possessing high elastic limit; but this tendency is opposed by the no less well-known fact that as the elastic strength of steel is increased by ordinary strengthening-influences, there is a reduction either in the static or the shock-ductility.

Mr. R. W. Davenport* remarks that an examination of the physical characteristics of this metal (nickel-steel) shows it to possess valuable qualities which explain its toughness and resistance to shock. The effect of nickel upon the elastic limit is, however, of the greatest importance, as it raises this quality in a marked degree, relative to the tensile strength, and thus insures a combination of elastic strength and ductility, or toughness, unknown in any other metal.

Nickel-steel shapes, beams, and T and Z bars, made for the United States navy, have been tested by Commander J. G. Eaton.

"The chemical and physical qualities are typified in the following record:

"Carbon, 0.25; sulphur, 0.023; manganese, 0.68; phosphorus, 0.010; nickel, 3.30; tensile strength, 87,580 pounds; elastic limit, 62,700 pounds; elongation in 8 inches, 22 per cent.; reduction of area, 52 per cent.

"The Z bar was one of a lot and not specially selected. It was unannealed and of basic open-hearth. Specimens 2 inches in width and 12 inches long closed cold on themselves, without sign of fracture and with a total absence of hair-cracks. The same bar was then annealed at a temperature of 1600° F. and again tested as follows:

"Tensile, 84,640 pounds; elastic limit, 59,500 pounds; elongation in 8 inches, 24.5 per cent.; reduction of area, 54 per cent.

"A bar of mild steel of the same chemical composition, but without the nickel, showed on similar tests:

"Tensile, 62,410 pounds; elastic limit, 36,420 pounds; elongation in 8 inches, 26.25 per cent.; reduction of area, 58.5 per cent.

"It needs only a glance at these figures to note that the gain to the working-load has been increased in the ratio of 36 to 59, or practically 64 per cent., while the elongation is at a figure sufficient for all ordinary purposes."†

The increase in elastic limit by the use of nickel in steel makes possible an increase in the span, or a decrease in the weight, of bridge-sections. The resistance of nickel-steel to jarring shock renders its use in eye-bars for bridge-construction particularly desirable. Such eye-bars are subject to repeated jarring strains; and the failure of an eye-bar means the collapse

* *Cassier's Mag.*, August, 1897, p. 525.

† Commander J. G. Eaton, U. S. N, "The Advantages of Nickel-Steel."

of a bridge. The necessity thus arising for the use of a steel with high elastic limit (about 70,000 pounds) has led to the use, in some cases, of 0.40-carbon simple steel. This percentage of carbon renders steel sensitive to heat-treatment; and, in heating to forge the eye, the bars are in danger of becoming crystalline by over-heating. The same high elastic limit can be obtained by using an 0.18- to 0.20-carbon steel, with 3 to 3.5 per cent. of nickel, which steel is much less liable to damage by overheating than the simple steel of higher carbon.*

Rivets.

Mr. Beardmore† reports that, having satisfied himself that nickel-steel was reliable, as regards punching, he had some rivets made of this metal, which were found to be considerably tougher than ordinary rivets. They gave a tensile strength of 35.7 tons (79,968 pounds) per square inch, with an elongation of 36 per cent. in 1.25 inches, and a contraction of area of 60 per cent., and were very ductile. An ordinary and a nickel-steel rivet were nicked with a chisel and hand-hammer and then broken. In the case of the nickel-steel the fracture was fibrous and the metal appeared to have torn gradually, whilst the ordinary carbon-steel rivet had broken short off.

Some very interesting and important experiments were recently made at the works of the Bethlehem Steel Co. by the Engineer of Tests, Mr. Maunsel White, for the purpose, not only of ascertaining the reliability and comparative efficiency of nickel-steel for general riveting, but also of observing the effects of working rivets of this material at different degrees of heat. The results were such as to remove all doubt as to the possibility of working these rivets safely within perfectly reasonable limits and with the exercise of only ordinary care. Two series of tests were made, the arrangement of the plates being for the first test as shown in Figs. 4 and 5, and for the second test as shown in Fig. 6.

The results of the first series of tests were as follows (see Fig. 7 and Table XXXIII., p. 631).

* E. F. Wood, Carnegie Steel Co. Private communication.

† "Nickel-Steel," *Inst. Engrs. and Shipbuilders of Scotland*, March, 1896; *Industries and Iron*, May 1, 1896.

FIG. 4.

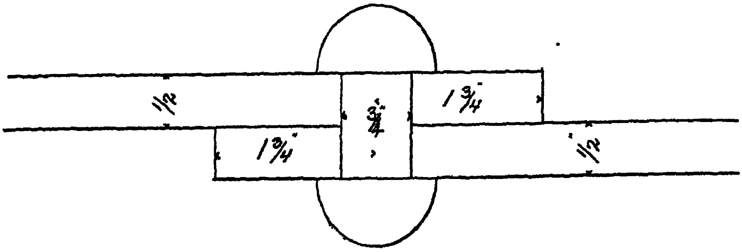
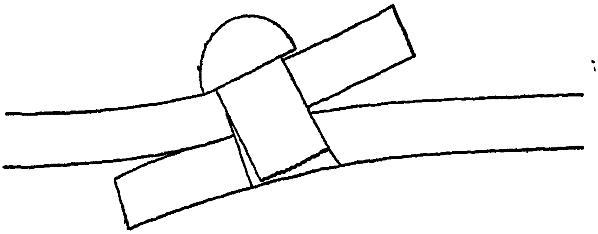
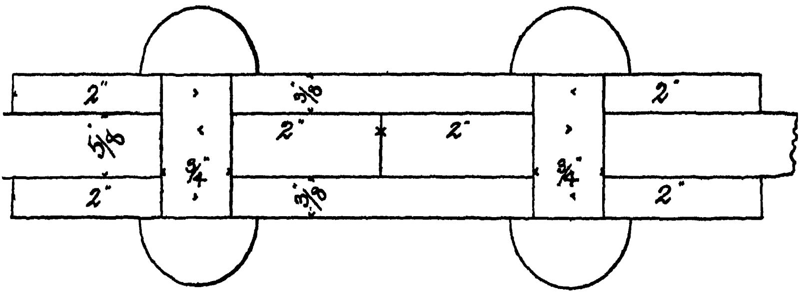


FIG. 5.



Method of Testing Nickel-Steel Rivets—Single Shear.

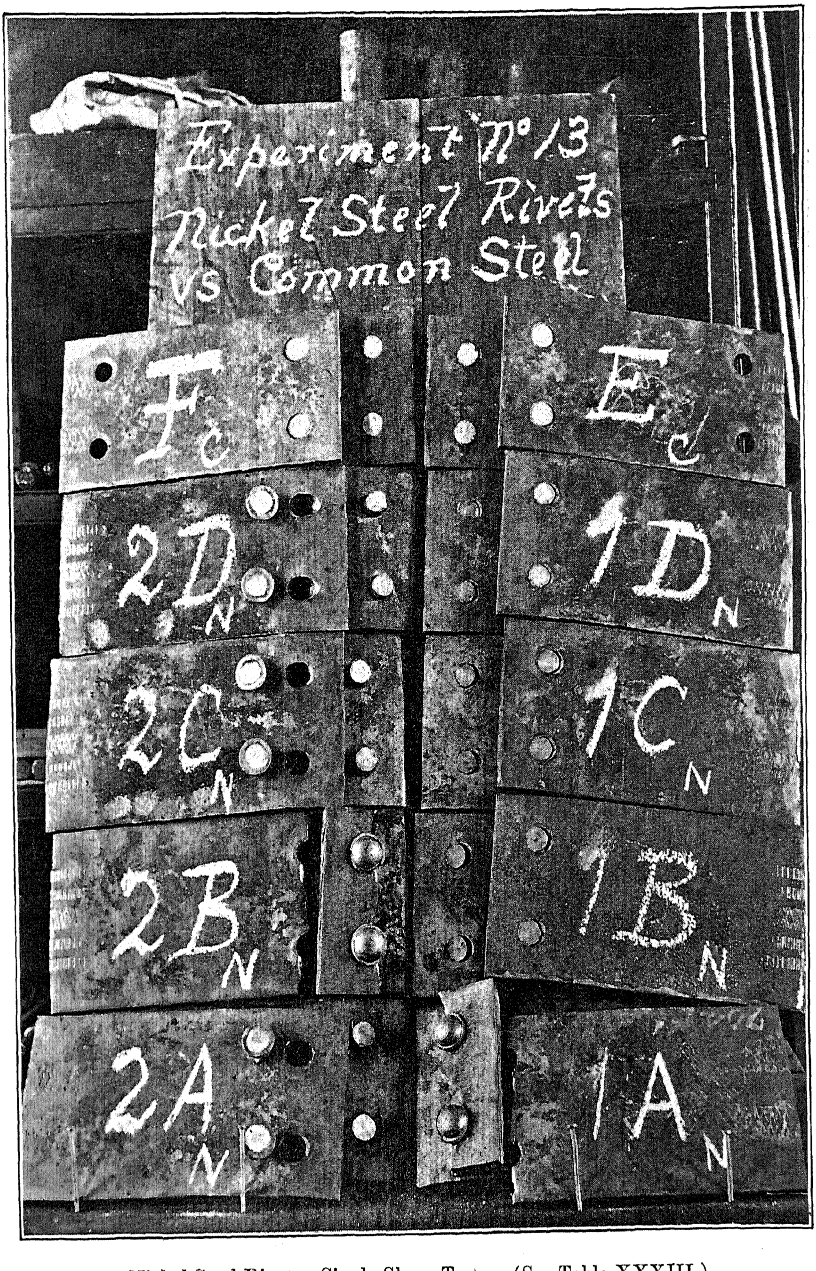
FIG. 6.



Method of Testing Nickel-Steel Rivets—Double Shear.

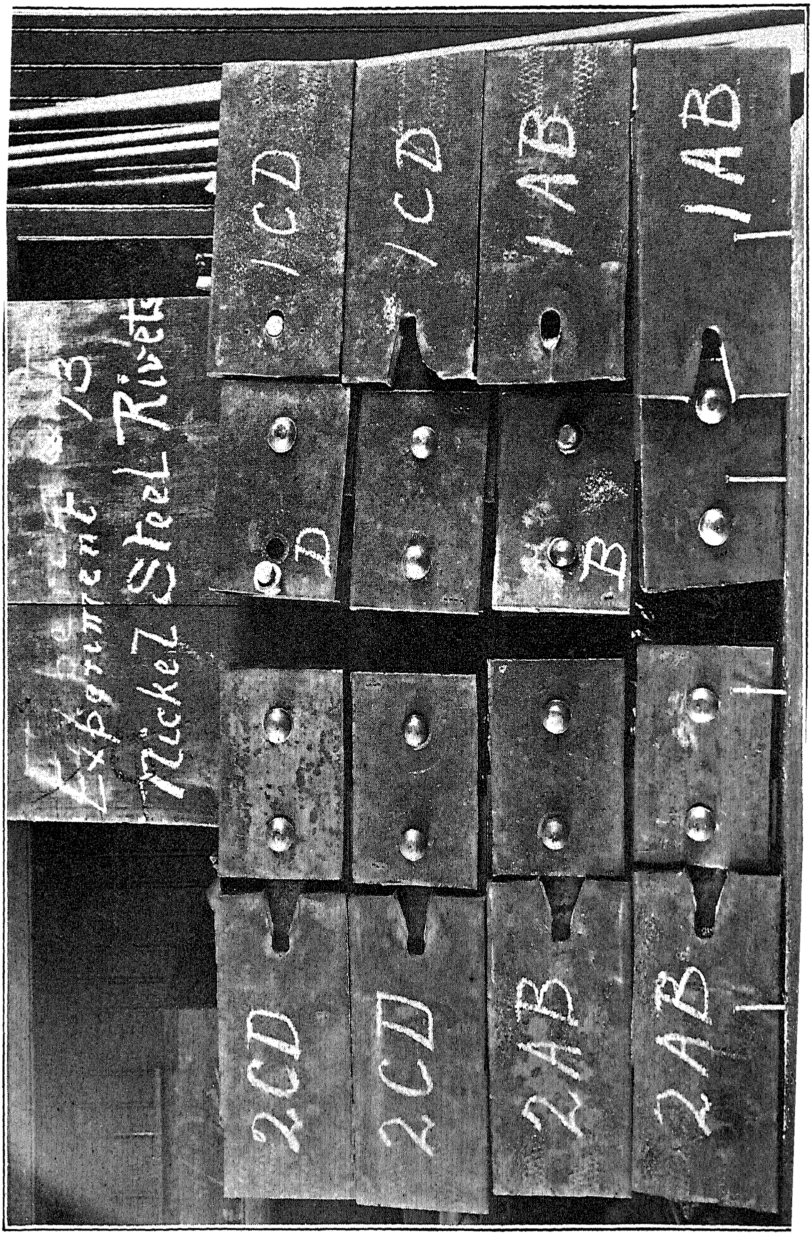
(From *Jour. Am. Soc. Naval Engrs.*)

FIG. 7.



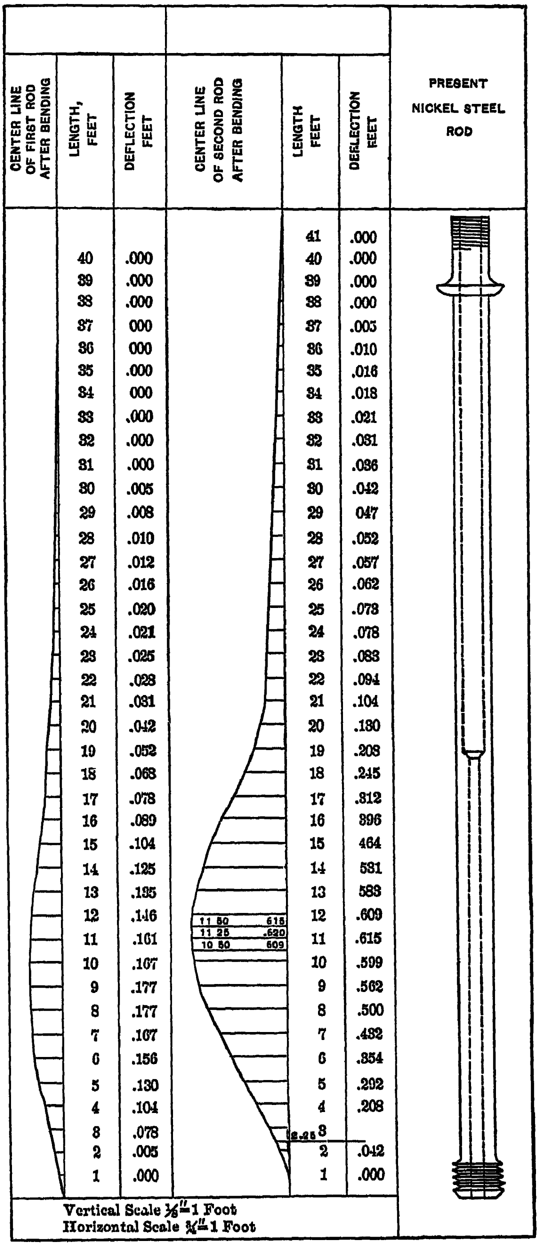
Nickel-Steel Rivets—Single-Shear Tests. (See Table XXXIII.)
(From *Jour. Am. Soc. Naval Engrs.*)

FIG. 8.



Nickel-Steel Rivets—Double-Shear Tests. (See Table XXXIV.)
(From *Jour. Am. Soc. Naval Engrs.*)

FIG. 9.

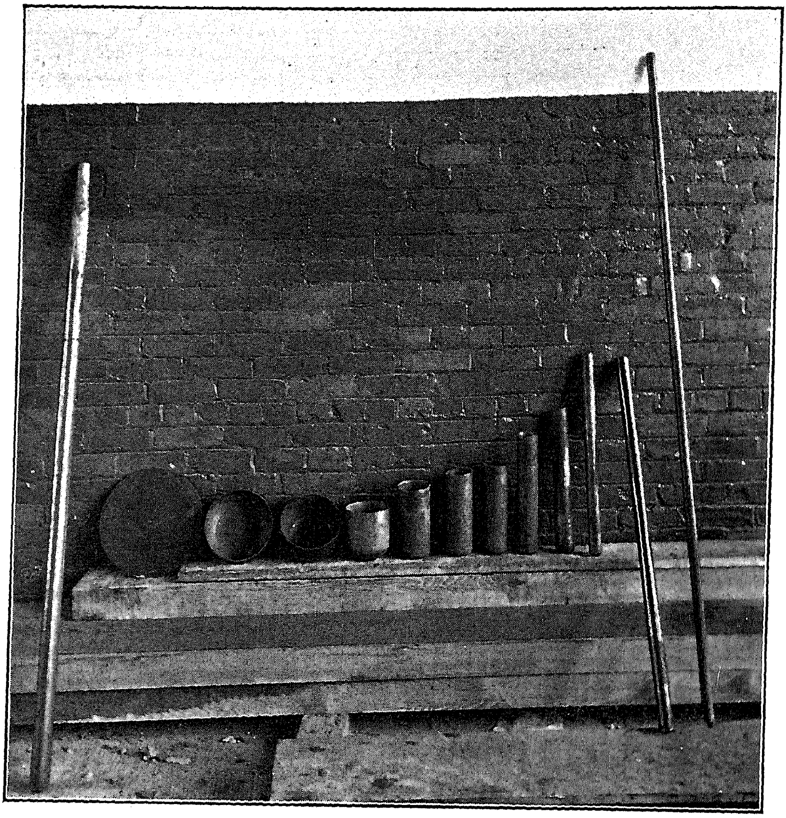


LENGTH, FEET	DEFLECTION FEET	LENGTH FEET	DEFLECTION FEET
		41	.000
40	.000	40	.000
39	.000	39	.000
38	.000	38	.000
37	000	37	.005
36	000	36	.010
35	.000	35	.016
34	000	34	.018
33	.000	33	.021
32	.000	32	.031
31	.000	31	.036
30	.005	30	.042
29	.008	29	047
28	.010	28	.052
27	.012	27	.057
26	.016	26	.062
25	.020	25	.073
24	.021	24	.078
23	.025	23	.083
22	.028	22	.094
21	.031	21	.104
20	.042	20	.130
19	.052	19	.208
18	.068	18	.245
17	.078	17	.312
16	.089	16	396
15	.104	15	464
14	.125	14	531
13	.135	13	583
12	.146	12	.609
11	.161	11	.615
10	.167	10	.599
9	.177	9	.562
8	.177	8	.500
7	.167	7	.432
6	.156	6	.354
5	.130	5	.292
4	.104	4	.208
3	.078	3	
2	.005	2	.042
1	.000	1	.000

COMPARATIVE FAILURES OF HIGH AND LOW-CARBON STEEL PISTON-RODS OF 125 TON HAMMER, BETHLEHEM IRON CO., BY H. K. LANDIS.

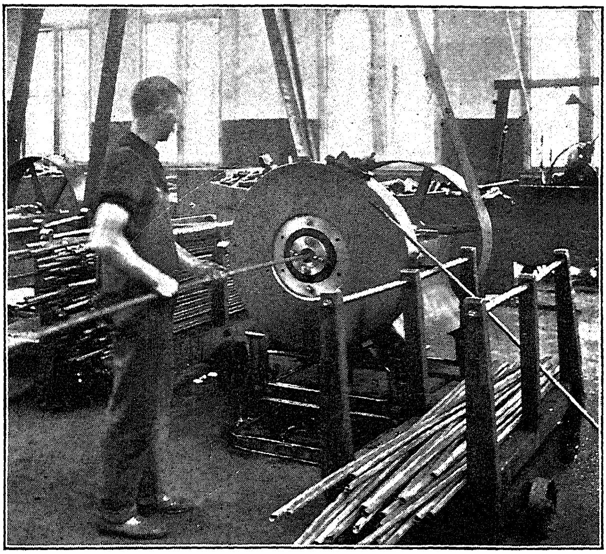
(From *Jour. Franklin Inst.*, vol. cxlv., p. 345.)

FIG. 10.



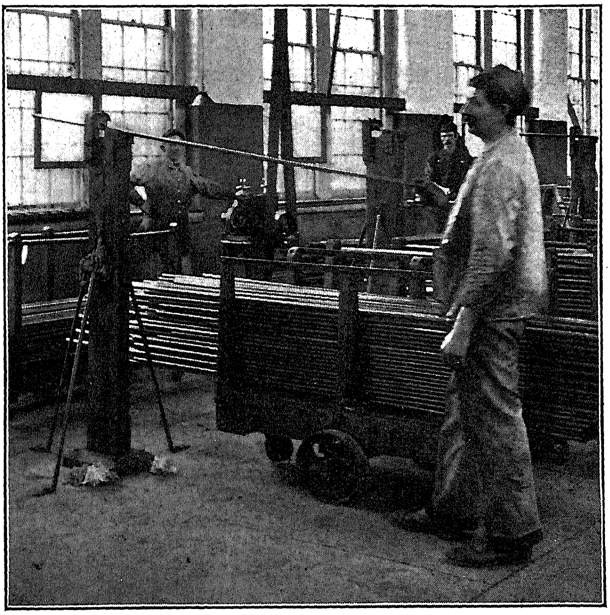
Stages in the Manufacture of Nickel-Steel Tubes, by the Pope Manufacturing Co., Hartford, Conn.
(From *Iron Age.*)

Fig. 11.



Making Nickel-Steel Tubes.

Fig. 12.

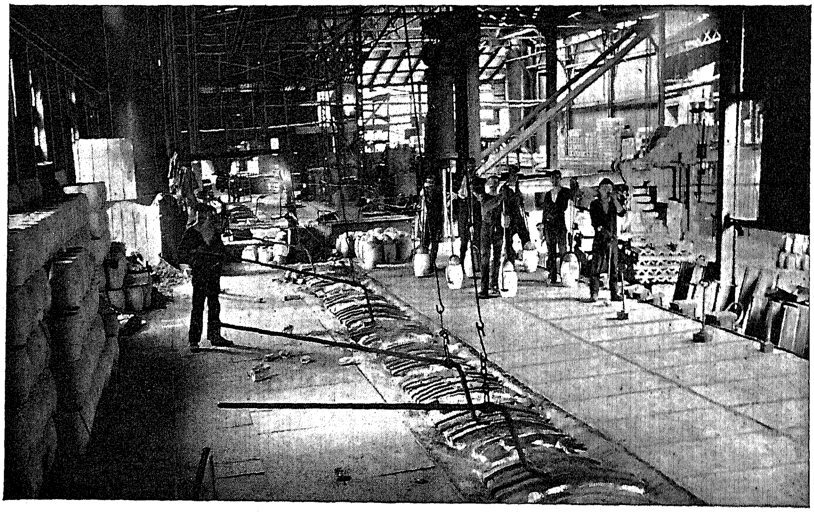


Straightening Nickel-Steel Tubes.
(From *Iron Age.*)

FIG. 13.

Nickel-Steel Slabs and Bicycle-Tubing, at the Works of the Pope Manufacturing Co., Hartford, Conn.
(From *Iron Age.*)

FIG. 14.



Interior of Works of the Crescent Steel Co., Pittsburgh, Pa., Manufacturers of Crucible Nickel-Steel.

TABLE XXXIII.—*Tests of Nickel-Steel Rivets.*

Mark.	¾-Inch Nickel-Steel Rivets—Single Shear. Breaking-Load. Lbs.	Nature of Fracture.	Shearing-Load. Lbs per Sq In
1 A	84,800	Plate broke.	88,330
1 B	87,600	Rivets sheared.	91,240
1 C	80,700	" "	84,060
1 D	78,400	" "	81,660
2 A	70,600	Heads broke off.	73,530
2 B	85,700	Plate broke.	89,270
2 C	90,900	Heads broke off.	94,680
2 D	79,700	" "	83,000

The letters A, B, C and D refer to the heat used in riveting, as follows: A, bright cherry-red; B, light-red; C, yellow; D, almost white. The numerals 1 and 2 coupled with these letters refer to the grades of nickel-steel used in the rivets.

The second series of tests was made with rivets in double shear. In these tests, two rivets in each plate were driven at different heats. In four joints, heats A and B were used, and in the other four joints heats C and D. The results of this second series, double-shear tests, were as follows (see Fig. 8):

TABLE XXXIV.—*Tests of Nickel-Steel Rivets.*

Mark	¾-Inch Nickel-Steel Rivets—Double Shear. Breaking-Load. Lbs.	Nature of Fracture.	Shearing-Load in Rivets. Lbs per Sq. In.
1 AB	78,550	Plate sheared.	87,200
1 AB	81,600	Rivet broke on one side.	90,550
1 CD	83,800	Plate sheared.	93,100
1 CD	74,050	Rivet sheared.	82,270
2 AB	84,200	Plate sheared.	93,550
2 AB	82,640	" "	91,820
2 CD	79,800	" "	88,660
2 CD	84,100	" "	93,440

In order to make some comparison between nickel-steel and the ordinary steel rivets, two test-pieces were made with ⅞-inch ordinary steel rivets, and were marked E and F. In single-shear, ½-inch steel plate was used, with holes 2 inches from edge of plate. In double-shear, ⅝-inch steel plates were used, with ⅜-inch steel-plate welts, and the holes were 2 inches from the edge. The results were:

TABLE XXXV.—*Tests of $\frac{7}{8}$-Inch Common Steel Rivets.*

Mark.	Breaking-Load. Pounds.	Nature of Fracture.	Shearing-Load in Rivets Pounds per Square Inch.
E, . .	53,200	Rivets sheared.	43,600 single shear.
F, . .	55,100	" "	46,000 double "

From these results Mr. White says it may be safely deduced that a $\frac{3}{4}$-inch nickel-steel rivet will replace a $1\frac{1}{16}$-inch, or even possibly a $1\frac{1}{8}$-inch, common steel rivet, thus effecting a saving of considerable plate-section and giving increased strength.*

These results, obtained in practical work, offer a very strong corroboration of the results deduced by Prof. Rudeloff in his experiments on the effect of nickel upon the shearing-strength of iron, referred to on page 597.

Steam-Hammer and Rock-Drill Piston-Rods.

The piston-rods for steam-hammers are particularly liable to what has been termed molecular fatigue: they are subject to continued shock, to resist which they must possess a very high elastic limit.

Fig. 9 shows the experience of the Bethlehem Iron Co. with rods for their 125-ton hammer.† The first rod was made from high-carbon open-hearth steel, [illegible]y forged, with a 4-inch hole running through the entire length, and having an outside diameter of 16 inches. The failure of this rod was attributed to partial crystallization and to its being too high in carbon, and, therefore, too brittle. These were the usual reasons given for failure under similar conditions in those days. Consequently, the next rod was made of a steel much lower in carbon, in the hope that it would withstand the effects of shock better. This supposition proved to be erroneous, and this rod failed after a shorter service than the first, and its failure was much more serious. About this time the advantages of material with high elastic limit became known, and the third rod was made of nickel-steel. The dimensions were changed somewhat: the outside diameter was changed from 16 to 17 inches, and the hole was made 8 inches in diameter for 22 inches from

* "Nickel-Steel Rivets," *Jour. Amer. Soc. Naval Engrs.*, 1898, vol. x., p. 1038. Figs. 4 to 8 inclusive have been taken from this paper.

† This statement is taken from the paper of Mr. H. F. J. Porter, *Jour. Frank. Inst.*, December, 1897, vol. cxlv., p. 347.

the top; the balance was made 7 inches instead of 4 inches, as before. This rod has fulfilled all expectations. The amount of deflection of the two rods which failed is shown in the figure, which exhibits also the character of rod now made for users of rods who want something that will last a long time.

At the Crescent Steel Works, in Pittsburgh, nickel-steel rods were substituted for carbon-steel in a battery of steam-hammers over a year ago. The hammers range from 300 pounds to 7 tons, the same material (3 per cent. nickel and about 0.30 carbon) being used in all. These rods have thus far given perfect satisfaction.*

In oil-tempering steel-forgings the objects to be tempered are suspended from a bar which carries a spider, and this bar is plunged into the oil-bath together with the object to be tempered. A bar of rectangular section [illegible] to this repeated heating and cooling tends to become cylindrical in section, and, if made of simple steel, will develop a longitudinal crack. As nickel-steel will, in this position, last much longer than simple steel, it is used for this purpose in the Bethlehem Steel Company's tempering- and annealing-department.

The same quality which enables nickel-steel to resist rapidly alternating strains renders it very serviceable in rock-drills, for which purpose it is largely used. The Sullivan Machine Company says on this subject:

> "Some years ago we made some experiments in the use of nickel-steel in parts of machines where we had previously used iron or open-hearth or crucible-steel. The parts mentioned were particularly liable to breakage, either from strain or on account of crystallization. After an experience of several years, during which we have considerably extended the use of the nickel-steel, we have become satisfied that it is an improvement over the iron and steel we had been using (though we had always used the best of ordinary products), the machine parts made from nickel-steel being less liable to break on account of weakness or crystallization. We believe also that the nickel renders the wearing parts of machines, which run on other parts, less liable to cut—the nickel apparently having the property of making the surfaces smooth with wear, even though not always properly oiled."†

This statement concerning the reduction of friction by the use of nickel is corroborated by the remarks of Mr. H. T. Williams, quoted above, under "Effect of Nickel on Hardness," and also below, under "Nickel in Tool-Steels."

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* Mr. McDonald, Crescent Steel Works. Private communication.

† T. W. Fry, Sec. Sullivan Machine Co., Claremont, N. H. Private communication.

Bicycle-Tubing.

On this subject Mr. Harold E. Eames* says, that in the consideration of the selection of a suitable material for bicycle-tubes, it should be borne in mind that not only must the bicycle provide strength enough to resist the maximum shock of any kind likely to be incurred in ordinary riding, but we must also insure that the life of the structural parts of the machine under the same conditions equals, if possible, that of the bearing and working parts. He adds that it would be necessary merely to select that composition of steel or its alloys which gave the greatest strength in the annealed state, and that steel alloyed with about 5 per cent. of nickel seems to fill this first requirement better than any other material in what might be called commercial existence.

This tubing, containing 5 per cent. of nickel, is made and largely used by the Pope Manufacturing Company, of Hartford, Conn. In its circular on the use of tubing the Co. says:†

"For handle-bars and shafts, seat-posts and rods, which admit of oil-hardening after all the brazing operations have been completed, nothing can approach the 5 per cent. nickel in rigidity and safety. In the oil-hardened state this material has developed an ultimate strength of not far from 240,000 pounds per square inch, with an elongation ample to afford insurance against sudden rupture. An oil-hardened nickel-steel handle-bar is both strong and tough, and fortunately is altogether beyond the realm of experiment, as not less than 150,000 of them have been produced and tested in actual use, with the greatest satisfaction to the manufacturer and rider. The use of this material also solves the difficult question of providing a seat rod which will really resist the collapsing effect of the saddle-clamp and a seat-post which will resist the effect of the head-clamp."

The following is a description of the manufacture:

From the plate of nickel-steel received from the manufacturer a circular disc is stamped out, as shown at the left in Fig. 10, which illustrates the several operations of cupping to which this steel is subjected. This blank is then taken to the double-acting hydraulic press; the blank is held between the two surfaces of the outer slide, while the center or drawing-slide, which has a much longer stroke, pulls the metal from between these surfaces and forces it through the center die, the result being a

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* "Consideration of Material for Bicycle Tubing," *N. Y. Iron Age*, June 18, 1896.

† Pope Mfg. Co. Circular on "Pioneer Tubing."

comparatively wide and shallow cup. The cup thus formed is absolutely free from any indication of wrinkle or crack at the side; and there is no evidence that the metal has been in any way tortured. The cup at the second drawing is reduced in diameter and considerably lengthened, the final operation being done upon the hydraulic draw-press, which is single-acting, *i.e.*, it is provided with only one plunger, which has a stroke long enough to give the shape shown in Fig. 10. The completed tube is shown in the same engraving, and one of the 0.50-carbon steel billets.* Figs. 11, 12 and 13 (taken, together with Fig. 10, from the *Iron Age*) further illustrate this manufacture.

Nickel in Tool-Steels.

The advantages gained by the use of nickel in the soft open-hearth steels seem to warrant the expectation that a corresponding gain would accrue from its use in high-carbon crucible-steels. The difficulties attendant upon the formation of such an alloy have deterred many from using nickel in tool-steels;—the ease with which nickel absorbs oxygen introducing an element of uncertainty into its manufacture.

Mr. H. J. Williams, of the Damascus Steel Co., of Pittsburgh, has given to this subject much experimental investigation, and the results of his researches are here for the first time made public. Mr. Williams says:

"The difficulty in the manufacture of nickel-steel for tools is caused by the tendency of nickel in the presence of high-carbon to develop seams, unsoundness and partial oxidation. These difficulties have been overcome, and sound billets of nickel-steel of any desired percentage in nickel or carbon can now be obtained.

"The working of these billets into tools or wire-rods presents no especial difficulties. The nickel-steel works tougher than simple steel; causes more rebound of the hammer and necessitates a lighter draught on the rolls or dies.

"For tools, the alloy containing about 0.80 carbon, with 3 per cent. of nickel, is probably the best alloy for every-day use. Increasing the nickel to 5 or 6 per cent. increases the strength,

* "The Manufacture of Bicycle Tubing; a Description of the Pope Tube Works," *Iron Age*, Jan. 7, Jan. 14 and Mar. 4, 1897.

but necessitates skilled treatment in forging. Tool-steel with 0.80 carbon and from 3 to 5 per cent. nickel, possesses all the hardness of high-carbon simple steel, without its brittleness. Nickel-steel shows very pronounced toughness. If nicked when hot, and then struck on the anvil after it has cooled, it is very liable to break under the hammer—not at, but beyond the nick; while carbon-steel almost invariably breaks at the point where it was nicked when hot. This nickel tool-steel has a satin grain and does not crack on quenching as readily as simple steel; the tensile strength runs as high as 260,000 pounds per square inch. A nickel-steel tool containing 4 or 5 per cent. of nickel, with 0.80 carbon, is as hard after tempering as the best simple tool-steel of 1.00 to 1.25 carbon, without the brittleness and glassy nature which distinguish the latter. When used for drills, the nickel-steel appears to work with much less than the usual friction, and does not become so hot in use as carbon-steel.

"Up to 6 per cent. of nickel, the hardness obtained by quenching is as largely dependent on the amount of carbon present as in simple steels, the only difference being that nickel-steels appear to attain a desired temper with 0.20 to 0.30 per cent. less carbon than simple steels. Nickel-steels are consequently exceedingly sensitive to heat-treatment, but, on the other hand, are less easily spoiled by overheating, and therefore may be worked at somewhat higher heat than a carbon-steel that will give the same temper."*

If the nickel be increased to over 6 per cent., tempering and hardening by quenching does not seem to have much effect upon the metal. This is especially noticeable when nickel rises above 12 per cent.; and at 18 per cent. the influence of carbon is almost neutralized. In the 18 per cent. nickel-steel the same hardness is obtained with 0.30 carbon as with 0.75 carbon, and the metal possesses its maximum of strength and elasticity at about this percentage of nickel. Further increase in nickel causes an openness of structure and a consequent softening.†

* H. J. Williams, Damascus Steel Co. Private communication.

† See Rudeloff, *Verein zur Beförderung des Gewerbfleisses*, Feb., 1896, p. 82. "Elasticity under pressure increases with increase in nickel, and the change of form by pressure decreases with increase in nickel up to 16 per cent."

Steel with 18 per cent. nickel and 0.60 carbon is perceptibly softened by heating and quenching; but if heated to redness and forged on the anvil till cold, it attains the same elasticity as a higher-carbon steel quenched in the usual manner. The 18 per cent. nickel-steel can readily be worked hot, but is exceedingly hard to punch and press cold.*

Steel with 25 per cent. nickel is very much softened by heating and quenching, and can be worked cold almost as readily as German silver.*

As the 18 per cent. nickel-steel is silvery white in color and has a soft luster, more resembling silver than steel, this alloy is particularly useful for table-ware and cutlery. For this purpose its non-corrodibility gives it a great advantage over simple steel, and its temper and hardness make it superior to German silver.†

An alloy of 3 per cent. nickel-steel with tungsten, and containing over 2 per cent. carbon, forms a self-hardening steel, similar to Mushet steel, with the advantage that it can be forged at the same heat as ordinary tool-steel.*

Hydraulic Cylinders.

The enormous power applied in the hydraulic compression of armor-plate and heavy ingots demands the use of exceptionally strong material in the cylinders. Nickel-steel has been very successfully used for this purpose at some of the largest forges in this country and Great Britain.

At the Parkhead forge, in Glasgow, a cylinder for a 12,000-ton hydraulic press was cast of nickel-steel. It weighed, as cast, 143,360 pounds, and was 72 inches in diameter. The machined cylinder weighed 76,160 pounds and showed an elastic limit of 56,000 pounds, with a tensile strength of 92,200 pounds per square inch.‡

At the Carnegie Works, at Homestead, Pa., it was discovered in 1896 that the five-piece cylinder of the 10,000-ton forging-press was developing a crack. As the makers could not replace this cylinder in less than eleven months, it was hastily decided to cast a cylinder of open-hearth steel, using enough

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* H. J. Williams, Damascus Steel Co. Private communication.

† See pages 603 and 606.

‡ Wm. Beardmore, "Nickel-Steel," *Trans. Inst. Naval. Arch.*, April, 1897.

nickel to insure maximum strength. A hollow ingot, of 0.25 carbon, with 6 per cent. nickel, weighing with the sinkhead 140 tons, was successfully cast. This is believed to be the largest hollow casting of nickel-steel yet produced. Considerable difficulty was experienced in erecting machinery of sufficient size to handle such a casting, but an impromptu lathe was finally erected, and the ingot was turned to the finished shape, in which it weighed 90 tons. This cast cylinder has now been in use for nearly two years and shows no signs of wear. It withstands an interior pressure of three gross tons to the square inch, and is undoubtedly the largest casting yet made of nickel-steel for hydraulic cylinders.*

Rifles and Small Arms.

The specifications for the Lee straight-pull rifles, supplied to the U. S. Government, read in part as follows:

"The material of which the barrels are made must be forged or rolled steel, oil-tempered and then annealed, and showing, on 2-inch specimens of standard form, an elastic limit of at least 80,000 pounds per square inch, and an elongation of at least 20 per cent. The above requirements can be met by an open-hearth steel containing about 4.5 per cent. of nickel; and such steel will be preferred."

The high ratio of elastic limit to ultimate strength conferred upon steel by the addition of nickel constitutes its chief merit for this purpose. No matter what the arm be, from revolver to hundred-ton gun, it is very desirable that the strength thereof should be *available* strength. In simple steel, annealed and tempered, the elastic limit of the metal is about 60 to 70 per cent. of the ultimate; that is to say, the gun-barrel may be deformed by a strain not much over half that required to produce rupture. For accuracy and safety it may be said that deformation is fully as undesirable as destruction of the piece. Any means whereby the amount of available strength in the weapon can be increased, and the useless strength and dead weight thereof can be decreased, is a boon to the manufacturer of arms and ordnance.

The Société Cockerill at Seraing, in Belgium, requiring for artillery and munitions of war a metal of very high elastic limit, and with sufficient malleability and ductility to insure its

† E. F. Wood, Carnegie Steel Co. Private communication.

working with ease, their engineer, M. Moulan, began five or six years ago to experiment with alloys of nickel and iron. Among other alloys, one of 7.5 per cent. nickel in pure homogeneous iron was produced. This metal seemed so nearly to fulfill the requirements that complete tests were made for comparison, both with iron and hard steel.

TABLE XXXVI.—*Tests of Ferro-Nickel, Iron and Steel.*

(Recalculated by H. K. Landis.)

Metal.	Limit of Proportionality. Lbs per Sq. In.	Elastic Limit. Lbs. per Sq. In.	Ultimate Strength. Lbs. per Sq. In.	Elongation. Per cent.	Reduction of Area. Per cent.
Ferro-nickel.					
Not tempered	35,270	70,389	76,800	24.3	60.4
Tempered at 900° C. in water	64,300	142,000	178,500	10.2	50.5
Ditto, and annealed at 500° C.	59,450	117,000	118,000	12.5	61.2
Tempered at 900° C in oil	55,750	139,000	142,200	9.3	42.3
Ditto, and annealed at 500° C.	49,790	115,800	120,000	12.2	52.5
Homogeneous Iron.					
Not tempered	6,500	29,870	53,900	29.4	64.9
Tempered at 900° C. in water	25,600	46,900	69,100	23.4	57.4
Ditto, and annealed at 500° C.	16,780	39,000	70,500	34.6	67.9
Tempered at 900° C. in oil	22,200	44,950	62,000	29.4	66.2
Ditto, and annealed at 500° C.	20,760	34,150	54,200	29.2	67.7
Hard Steel (0.55° C).					
Not tempered		73,400	122,000	12.1	24.4
Tempered at 900° C. in water		75,600	105,000	22.	.9
Ditto, and annealed at 500° C.		114,000	143,500	7.7	27.3
Tempered at 900° C. in oil		101,800	132,800	1.8	4.7
Ditto, and annealed at 500° C.		112,000	150,760	9.8	27.3

As will be seen from these tests, all the advantages are on the side of ferro-nickel. This alloy, after oil-tempering and annealing, shows an elastic limit of 90 per cent. of the ultimate strength; while in the hard steel the same treatment raised the elastic limit only to 74 per cent. of the ultimate. In practice this means that, of the total weight of a gun-barrel, 36 per cent. is, in the case of carbon-steel, useless weight; while in ferro-nickel only 10 per cent. of the weight is unavailable in action. Since these tests were made, M. Moulan has used ferro-nickel alone for field-pieces and artillery-equipment.*

* *Stahl und Eisen*, April 1, 1895, vol. xv., p. 346; *Rev. Univ. des Mines*, xxvii., p. 152; *Industries and Iron*, Nov. 2, 1894.

Resistance-Wire.

The high electrical resistance of alloys of iron with 25 to 30 per cent. of nickel has led to its use in electrical machines instead of German silver. "Tico" resistance-wire, made by the Trenton Iron Company and containing about 28 per cent. of nickel, is largely used for resistance-coils in rheostats and electrical heaters. It has considerable advantage over German silver in having three times as much resistance, and retaining its strength and elasticity even after heating to bright redness. No. 14 B. & S. Tico wire averages 8 feet to the ohm of resistance; the same size of German-silver wire requires in practice 25 feet to the ohm.*

A similar resistance-wire, known as "Climax" wire, containing about 24 per cent. of nickel, is made by Roebling's Sons Co. This wire has a specific gravity of 8.137, a resistance per mill-foot at 75° of 504.86 ohms, and a temperature-coefficient of 0.042 per cent. per degree F.

Another nickel-iron resistance-wire, made in Germany, and containing about 29 per cent. of nickel, has specific gravity 8.4; specific resistance at 20° C. (68° F.) of 86 microhms; a coefficient of temperature of 0.00065 for 1° C., and a resistance per mill-foot of 517.5 ohms.

The specific resistance of German silver is on the average, at 20° Centigrade, 31.5 microhms.

Owing to their high percentage of nickel, these wires are nearly incorrodible, and, owing to their high tensile strength, they are much less liable to break than German silver. After repeated heating and cooling, German silver becomes brittle, while nickel-iron alloys seem to retain their original elasticity.

Miscellaneous Uses.

There are a number of purposes for which nickel-steel is used, but concerning which commercial rivalry prevents the publication of reliable data. For locomotive fire-boxes, boiler-braces and stay-bolts, bicycle-spokes and chains, torpedoes and torpedo-nets; incandescent lamp-mantle hangers; rolls for tubing and for planished sheets; [illegible] revolvers and small-arms;

† J. E. Storey, Storey Motor and Tool Co., Trenton, N. J. Private communication.

safety-deposit vaults; bobbin-spindles; teeth for cotton-pickers, and for a great variety of purposes for which some peculiarity, either of strength, ductility or incorrodibility, gives it especial fitness, nickel-steel is rapidly making its way into popular favor.

The peculiar electrical and thermal coefficients possessed by the alloys of steel with high percentages of nickel, suggest numerous uses in electrical appliances and instruments of precision. All the nickel-steel alloys are remarkably homogeneous, easily worked and susceptible of a high polish.

M. Zetter, director of the French Electrical Equipment Co. (*Compagnie Française d'Appareillage Électrique*), has made numerous experiments on the nickel-steels which lose their magnetism on heating and recover it on cooling. He has used these metals in the manufacture of circuit-breakers, automatic fire-alarms and other instruments, in which an electric circuit is broken by a rise of temperature, produced either by the heating effect of the current or by an external source of heat. He finds these instruments to act with regularity and accuracy.*

M. Dupriez suggests that as the temperature at which magnetism is lost and regained in nickel-steel is a regular function of the amount of nickel present, the 30 per cent. alloy which loses magnetism at 100° C. and regains it 50° may be utilized in the construction of a thermo-electric machine for the direct conversion of heat into electrical energy.†

From Table XXXVII, showing the effect of varying amounts of nickel on the coefficient of expansion, it will be seen that the coefficient falls from 28 to 36 per cent., and then rises again. At 36 per cent. the expansion is only one-tenth that of platinum. Platinum expands about 1 part in 208,800 for a rise of one deg. F. The 36 per cent. nickel-alloy expands 1 part in 2,049,000 parts.

Expressed in the usual way, temperature being read in degrees Centigrade, the expansion-coefficients of some of the common metals are:

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* Guillaume, "Les Aciers au Nickel. *Comptes Rendus*, March, 1898.

† M. Marcel Dupriez, *Rev. Gen. des Sciences*, Feb. 15, 1898.

TABLE XXXVII.—*Coefficients of Expansion.*

Brass	0.00001878
Copper	0.00001718
Soft steel	0.00001078
Hard steel	0.00001239
Nickel	0.00001252
26 per cent. nickel-steel	0.00001312
28 " "	0.00001131
28.7 " "	0.00001041
30.4 " "	0.00000458
31.4 " "	0.00000340
34.6 " "	0.00000137
35.6 " "	0.00000087
37.3 " "	0.00000356
39.4 " "	0.00000537
44.4 " "	0.00000856
Platinum	0.00000884
Glass	0.00000861

From this table it will be seen that a nickel-steel alloy may be made to have a coefficient of expansion which may vary within wide limits. Alloys of the same expansion as glass may be prepared, either with about 29 per cent. nickel or with about 45 per cent. nickel. For all lens-mounts, telescopic and microscopic, and in general for all optical purposes where glass and metal are brought in contact, these alloys have a wide field of usefulness.

For instruments of precision in which extreme accuracy is desirable, the 36 per cent. nickel-steel may be used to great advantage, instead of brass. It expands and contracts with changes of temperature only one-twentieth as much as brass; is very much stronger and more rigid, and hence allows a reduction of weight in the instrument; and, as it is very much less affected by moisture and corrosive gases, and retains a silvery color and polish under adverse circumstances, its advantage for scientific instruments is very evident.

In mercury-pendulums or compensation-pendulums, the weight of mercury or the length of the compensation-bars can be greatly reduced by the use of the 36 per cent. nickel-steel; and by replacing a common pendulum with one of this alloy, the daily variation due to temperature will be diminished in the proportion of 12 to 1.

The incorrodibility of nickel-steel points out its usefulness in pumps, mine-cables, wire-ropes used near roasting-

furnaces, and all other situations where necessary exposure to corrosive liquids or gases renders simple steel unserviceable.

V.—Cost of Nickel-Steels.

At the present cost of nickel—33 to 36 cents per pound—each percentage of nickel adds one-third of a cent to the cost per pound of steel. The usual addition of 3 per cent. nickel increases the cost of the raw metal 1 cent per pound. After the steel is cast, the alloy costs no more to work than simple steel, excepting the slight additional cost entailed by keeping nickel-steel scrap in a separate stock-pile.

Finished forgings for moving parts of engines vary in price according to the intricacy of the pattern; and in simple steel forgings the cost may run from 3 or 4 cents per pound up to, and even over, 50 cents per pound of finished product. The use of nickel-steel for fine shafting, connecting-rods, crank- and cross-head pins, may increase the cost 15 to 25 per cent. over the figures for simple steel forgings. The increase in efficiency varies with the amount of carbon present, and runs from 40 per cent. in the soft steels to over 60 per cent. in the hard steels; while in the case of very hard tool-steels, the effect is said to be much greater.

As this gain in efficiency may be utilized either to decrease the weight of the part, or to increase the amount of work done, the net saving effected by the use of nickel is very evident.

Capt. W. H. Jaques, U. S. N., writing in 1895, estimated that even at the then comparatively high price of nickel, there would be a saving of $64,000 in the item of armor alone for each of the British battleships, if nickel-steel carburized armor were substituted for the plain steel Harveyized armor-plate which it was proposed to use.

For hull-plates of large steamships, the use of nickel-steel would effect a large saving in weight and displacement, and the increased freight- or coal-capacity gained thereby would add a large percentage to the efficiency and earning-power of the vessel.

VI.—Manufacture of Nickel-Steels.

Nickel melts at about 1650° C., a heat a little above that of molten steel. The nickel-steel alloys melt as readily as simple steel. Nickel cannot therefore be added in the ladle, as may

be done with spiegel or aluminum, but must be alloyed directly in the crucible or open hearth. It may be used either as oxide or as metal. The dry oxide, when pure, contains about 77 per cent. of metal. The usual method of adding nickel, as oxide, in the open hearth, is to enclose the oxide in a rough box of wood or iron, with sufficient charcoal to reduce it to metal. This is placed upon the hearth, scrap- and pig-iron are added, and the charge is worked in the usual way. The use of metallic nickel is, however, to be preferred, as the loss by slagging is not so great. In open-hearth work the loss is estimated as the same as that of iron, viz., 7 to 8 per cent. of the charge of nickel.

In crucible-work metallic nickel alone should be used; and the loss in this case is very little. The nickel is added in the crucibles with the rest of the charge.

In working nickel-steels care should be taken to avoid chilling the metal. It is extremely sensitive to sudden, even though slight, changes of temperature and careless handling. Contact with wet or cold ground, exposure to rain, or any other sudden chill may cause a surface-hardening that will interfere with proper working.

In hammering, rolling, pressing or wire-drawing, less draught should be given than with simple steels of the same carbon. In general, soft steels containing nickel should be treated like high-carbon steel. Once the metal is cold, it can be depended upon to resist rough handling and unskilled treatment, but while hot it should be treated with the care and respect due to a metal of such unique properties and phenomenal possibilities.

VII.—Makers in the United States.

The Carnegie Steel Co., the Bethlehem Steel Co. and the Midvale Steel Co. manufacture large amounts of open-hearth nickel-steel for the United States government and for private trade. These firms possess large experience, and every mechanical facility for the manufacture of nickel-steel in any quantity or shape desired.

The Carbon Steel Co., of Pittsburgh, makes a specialty of open-hearth nickel-steel for engine-forgings, locomotive-parts, boiler-sheets and stays, and fire-boxes.

The Crescent Steel Co., of Pittsburgh, deals more exclusively

with crucible-steel, and produces special grades of hard or high-carbon steel for tools, hammer- and piston-rods, etc. Fig. 14 shows the interior of these works.

The Damascus Steel Co., of Pittsburgh, makes a specialty of steel containing large percentages of nickel for cutlery, bicycle-spokes and chains, and extra-hard tool-steel for lathes and planers. It produces also a self-hardening nickel-alloy resembling Mushet or tungsten steel.

The Pope Tube Co., of Hartford, Conn., manufactures nickel-steel tubing for bicycles, and possesses every appliance for the production of nickel-steel tubing for light boilers, gas-engines, and all kinds of motors.

The Trenton Iron Co., of Trenton, N. J., manufactures "Tico" wire, a high-grade nickel-steel wire, for heaters and resistance-wire; and

The John A. Roebling's Sons Co., of the same place, manufactures and sells a similar product, under the name of the "Climax Resistance Wire."

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APPENDIX:

Prof. H. M. Howe, in a private letter, reports, as a later statement of comparative tests of nickel- and other steel than that presented in Table XXVI. of this paper, the following table:

Loss of Weight in Pounds Per Square Foot of Surface Per Annum When Exposed to Water.

	Sea Water.	Fresh Water.	General Average.
Wrought iron,	0.1409	0.1275	0.10386
Soft steel,	0.1612	0.1204	0.10906
Low nickel-steel,	0.1173	0.1021	0.08299
High nickel-steel,	0.04518	0.04404	0.03416

The Characteristics and Conditions of the Technical Progress of the Nineteenth Century.

BY JAMES DOUGLAS, LL.D., NEW YORK CITY.

(Presidential Address at the California Meeting, September, 1899.)

At this last meeting of our Institute for the year 1899, it is appropriate that we should look back at the past.

To review the century's progress in the exact sciences and the resulting arts that fall within the scope of our labors is beyond my ability. But I wish to draw your attention to some phases of that progress, almost as important, which lie within the zone of sociology, touching at so many points the domain of applied technology. One of these is suggested by the library of technical literature which this century has produced —not the least important contribution to which is our own *Transactions*.

The nineteenth century has witnessed the beneficial spread of democracy in politics. Under the impulse, to no small degree, of the same spirit, there has grown up a brotherhood of fellow-workers and a sense of fellow-ownership in the secrets of nature. Though the Patent Office has assumed such proportions as to have become a source of national revenue, and a multitude of inventors, great and small, are seeking through its agency to secure some pecuniary profit from their devices, there is even greater eagerness among both interested and disinterested workers in the field of technology to publish their observations, and even their discoveries, and to give them to the world without remuneration. The motives influencing the great body of writers who, without any pay, use the technical journals and such media of communication as our *Transactions*, in order to give to the brethren of their craft the results of

their often dearly-earned experience, are various and complicated. But, in the majority of cases, the impulse originates in the desire for reciprocity, and in the hope that others will tell what they know, in return for what we ourselves communicate, and that therefore we shall learn at least as much as we can teach.

The spread of this healthy desire for liberal intercourse is assisted by the increase of means and opportunities for its gratification. Meetings such as this, for the personal interchange of thoughts and experiences, after a journey of 4000 miles, are possible only through the aid of railroads. The dissemination of our *Transactions* and of the great bulk of technical literature can be effected only through a government Post Office, working for the public good, and, in some of its departments, at unprofitable rates. These agencies have been the product of the nineteenth century, and only under their stimulus and through their machinery could such efforts be rendered practicable as technical men, the world over, are making for the furtherance of their common pursuits, interests and aims. Attribute the movement to what cause we may, I think it is fair to claim as one of the glories of the vanishing century the development of the spirit of open-mindedness and fraternal helpfulness, even in such self-seeking pursuits as those in which we are engaged. I use the word "development" advisedly; for I am far from admitting that progress in this direction, great as it has been, has reached the consummation of intercommunication which the twentieth century will witness, and which will aid mightily in the further advancement of science, as well as of art.

To-day, more than ever, technical experience is not only more freely discussed and disseminated than ever before, but the results of that experience, carried into actual practice, are more unreservedly than ever thrown open to technical inspection. The proof of this we, visiting members in attendance at this meeting, have experienced at every step of our journey. There are few great metallurgical works in this country, entrance to which is refused to a visitor who has any real right to ask for admission.* In Europe, even, where old conservative

* This observation does not apply in full force to chemical manufactories, where there are supposed to be more secret processes worked behind-doors than in any other branch of technology.

practices are more enduring than here, the barrier of exclusiveness is being rapidly broken down. As a rule, those establishments whose doors are most sedulously closed are those least worth studying, except as technical anachronisms.

Moreover, I think it may be accepted as a fact that those branches, especially of metallurgy, which have made most progress, are those in which least secrecy and reserve have been practiced. No art has made such marvellous strides as the manufacture of iron and steel. Speaking from my own experience, I may say that I have never been refused admission to any iron- or steel-works on either side of the Atlantic, not even the works of Mr. Frederick Krupp, at Essen. But though iron-masters abroad may freely throw open their doors, our own American iron-masters are even more liberal in communicating their plans and methods. Managers from England, smarting under American competition, who have come to this country to visit our furnaces and rolling-mills, with the avowed object of borrowing their plans, have expressed to me the greatest wonder and admiration at the frankness with which they are allowed to study the great works which have demoralized prices the world over.

Not only do the iron- and steel-workers of every land bid their rivals enter and view the titanic feats which each vies with his neighbors in performing:—they seem to take delight in telling their very secrets. Certainly no special literary organ of any art contains such frank discussion of processes and methods as the "Journal of the Iron and Steel Institute," which is not the Institute of Great Britain, as popularly supposed, but of the world. Such periodicals as the "Iron Age," and other organs of the iron-industry in its several phases, illustrate the liberality of the iron men in even giving their working-plans to their fellow-workers. It may be inferred, therefore, with justice, that the progress achieved in iron- and steel-making, and the delightful candor with which iron-masters discuss their trials and tribulations and explain the solutions of their difficulties, are related, not accidentally, but intimately, as cause and effect.

I wish I could say the same, as unreservedly, for the branch of metallurgy in which I am more immediately interested—that of copper. Some of our largest works still close their doors against strangers. The only locality, however, where rigid secrecy is almost completely maintained is Swansea; and there, I imagine,

we would find, if admitted, little to learn which was not described generations ago. Is it not possible that one reason why we are now robbing Swansea of so much raw material, coming even from British colonies at the antipodes, is that she refuses to either give to, or take from, the world's supply of technical information? The managers of such progressive English works as those of the Cape Copper Co. and the Rio Tinto Co., where there are actual novelties to be studied, are willing to throw them open to students.

As an example of what might be gained by interchange of experience, I may be allowed to draw an illustration from a branch of copper-metallurgy. In this country and Europe there is a refining-process, the operation of which some, though not all, of those who practice it, guard from inquisitive eyes with timorous care. I refer to the electrolytic process. But I need not remind those of you who attended the recent New York meeting, still less those who have just visited the electrolytic establishments at Great Falls and Anaconda, that this dread of inspection does not possess the managers of all our great copper-works. It is understood that this is a branch of metallurgy dependent for success on the nice adjustment of a number of chemical and physical factors, and that the sixteen or eighteen works which practice it on a large scale in this country and in Europe have acquired only after much trouble and serious expense the experience which enables them to turn out copper of invariable quality with almost absolute certainty. After spending time, labor and money in overcoming the difficulties which mysteriously and unexpectedly turn up, the owner of a copper refinery deems it unbusinesslike to divulge the solution of these problems, and thus place his rival's works on equal footing with his own. But, in reality, his rivals have all been battling with exactly the same foes, and most of them have been victorious. The result, therefore, of a mistaken reticence is, that each of the works has had to expend, in surmounting exactly the same obstacles, six or seven times more money and energy than if all had been willing to interchange experiences. There is very little to choose between one brand of electrolytic copper and another. All are good; and all have been brought to the present high standard by separate labor and separate series of experiments, in separate establishments; whereas, had there been co-operation on points of purely

technical manipulation, the same results would have been attained with an immeasurable saving of time, mental wear and tear, and financial expenditure. It is difficult for a skilful manufacturer to appreciate and admit this. But that a truer appreciation of the value of the higher principle of co-operation has taken possession of our copper-refiners is evinced by the publication of such a paper as that of Mr. Keller, the representative of the Anaconda Co. with the Baltimore Copper Co., in the last volume of the *Mineral Industry*.

I have used the above instance, drawn from copper-metallurgy, as an illustration of the wasteful effects of secrecy, and because it stands out in such glaring contrast to the nobler practice of mutual helpfulness, which has been one of the most potent forces in raising all manufacturing, but especially that of iron and steel, to the exalted position it has attained during the latter half of the century with which we are regretfully parting.

As time goes on, and a generous dissemination of personal knowledge, even if it be not strictly practical, becomes the rule and not the exception, it will be discovered that, after all, success in manufacturing will depend as much on the personal energy and skill with which the knowledge is applied as on the possession of the knowledge itself.

Whether we will or not, secrecy, as a business method, is becoming almost obsolete under the prying scrutiny of the press and the telegraph. The old rules of business, dependent on reserve and on news secured in advance of one's neighbor, have given place to new methods. The chronicle of the world's doings is at the disposal of any one for a few cents, every morning of the year. But the man of business genius draws from it conclusions very different from those of his less imaginative or less enterprising rival. Both men may possess, as stock in trade, the same facts, but the abler man makes successful use of them. His correct and far-sighted deductions lead him to adopt a policy and pursue a course of action as different from those of his sluggish competitor as if he had himself possessed special sources of information.

And so it is in the practice of our peculiar arts. The personal element determines the success of one man and the failure of another, though both start out with the same store of facts. Nevertheless, the more facts he has, the more rapid will

be the rise of the man of genius, while the pace of the other will certainly not be retarded. The man of genius, therefore, need not grudge the communication of his facts to his less progressive competitor, provided he learns, in exchange, what few facts his slower neighbor may have picked up by the way. While all must admit that the world's rapid advance in material well-being has been due to the dissemination of knowledge, and that this can be effected only by the breaking down of the barriers of secrecy, some of our brethren have yet to be persuaded that there are few, if any, limitations to be set to this universal law. Unfortunately, many barricades, raised by mistaken selfishness, are still to be stormed and demolished. But the coming century will in this respect carry forward the work of the receding age, whether we shall see its accomplishment or not. At any rate, we may congratulate ourselves that societies such as ours have aided to further so good a cause, not only as media of communication, but also as sources of influence—for the most confirmed secret-keeper cannot benefit by the candid revelations of his rival without some compunction; and, sooner or later, reform follows repentance. It is, therefore, not presumptuous to hope that, as the scientific temper more and more permeates the habits of our technical workers, the old fashion of relying on secrets for success will be replaced by the truer method of generous giving and thankful receptivity.

At present the world's acquisitions in pure, and, to a great extent, in applied science, are thrown into a common stock, from which the technical worker draws what he wants without stint. He, in his turn, is coming to acknowledge and recognize the truth that it will be to his advantage to enlarge the sphere of unreserved intercommunication until there shall be no trade-secrets; for then, while society will be the gainer, he himself will be able to draw from a larger capital of facts than now stands to his credit. Moreover, it may be accepted almost as a law of nature that the person who has not cultivated the habit of mental giving acquires a spirit of narrow exclusiveness which cramps the faculty of open-minded receptivity—for receiving and giving are reciprocal intellectual motions.

Though the influence of individuals on the industry of the country is keenly felt, national progress, in its widest range,

is not made through the impelling force of one man, be he ever so able. It results from the united efforts of many minds and many hands, acting under the contagion of a common inspiration. Looking at the development of a whole people, or of a single industry as a unit, we may therefore perceive that the old habits of secrecy in manufacturing enterprises frustrate the very object which the secret-keeper aims at; for while he is guarding behind double doors his depreciated treasure, the great army of progress is marching past him.

To a certain extent, community of ideas and methods is secured through such combinations of capital and manufacturing interests as have become the most prominent features of modern industrial development. All the peculiar processes and methods (if there be such) practiced by each of a dozen combined mills become the property of the unified concern, and can be applied in all its establishments. But should the result of industrial combinations be the reversal of the tendency towards freer discussions, and should the managements of these tremendous aggregations of power prohibit on the part of their employees all discussion of technical subjects, a strong prejudice against their existence would be created in the public mind, which naturally distrusts all secretiveness. The public will not unreasonably conclude that if one of the great economical benefits which accrue from such combinations is the "probing" of individual secrets, much greater would be the general benefit if all reserve should disappear, and the technical facts learned by one should be communicated to all, as freely as Röntgen gave to the world his discovery of the "X" rays. Ours is stigmatized as a mercenary age. Nevertheless, there is a spirit of fraternal helpfulness abroad in the world. I believe that before long he will be honored as the most successful man who has communicated to his fellow-craftsmen the greatest number of useful facts and the largest stock of valuable personal experience; and I believe, also, that any combination of selfish men or interests which may try to withstand this rising tide of free thought and free speech will be swept away.

As I have already remarked, this modern spirit of voluntary interchange of thought and experience has been stimulated by the means of transportation and communication which alone have made its effective operation possible. Railroads, steam-

boats and the telegraph have been the apostles and missionaries of free thought and free speech. But they have served another purpose. They have virtually determined the current of population and the drift of mining and metallurgical industry.

It is difficult to realize the diminutive proportion of human settlement on this continent during the first three decades of this century. In the year 1800 the population of the United States was 5,305,937. There were only 903 post-offices and 21,000 miles of post-roads,—and very bad roads at that. The Post Office revenue amounted to only $231,000; and only four cities could boast of a population exceeding 10,000 inhabitants.

In 1830 the population had increased by natural increment to 12,860,020. But the manufacture of metals was still a local industry; and so it continued for nearly two more decades—while the railroad system of the country was expanding, so as to link section with section and fuel with ore. The year 1830 was economically the critical period of our history, for in it the railroad first appears as a factor in our industrial life. Twenty-three miles of track had been laid. By 1840 locomotives were running over 4535 miles of road. In that year the first attempt was made to incorporate industrial statistics by quantity, instead of value, in our census-returns. If we compare two items of the statistics of 1840 with the same in 1897, we shall appreciate how potent the railroad has been as a controlling power in mining and smelting, and what a revolution it has wrought in the industrial life of the nation.

In 1840 there were 804 small furnaces, making 256,100 tons of pig-iron, and in 1897 there were 191 large furnaces making 9,652,680 tons; while in 1898, 11,773,934 tons were made, and in the latter part of the present year it is estimated that the production has reached the rate of 15,000,000 tons per annum.

If we multiply the number of miles of railroad and the number of tons of pig-iron made in 1840 by 40, we get as a product approximately the figures of 1898, viz., 10,244,000 tons of pig (exact figure 9,652,680) and 181,400 miles of railroad (exact figure 184,603). The magnificent iron-industry of the country has thus kept pace with the extension of its railroad-system. The lines of growth have not always been parallel; but the harmony of growth between the two greatest forces of our in-

dustrial progress has not been accidental. Equally important in its bearing on the iron-trade has been the development of inland navigation. The difference between the first steamer, "Walk on the Water," that timidly ventured out on Lake Erie, and the present large iron steamers, which, with their consorts, last year transported 14,000,000 tons of iron-ore from Lake Superior ports, is as great as between the "John Bull" of the Mohawk & Hudson R. R. and No. 999 of the N. Y. Central and Hudson River R. R. With increased size and improved machinery in vehicles on land and water, the cost of transportation has correspondingly decreased, until freight has been carried, on long-distance hauls, with profit to the railroad company, for four mills per ton-mile.

The statistics of the Fitchburg R. R. give us as the average freight-rate in 1848 as 4.523 cents, and in 1897 as 0.870 cent per ton-mile. When Lake Superior began to ship iron-ore, in 1857, the transportation-charges were about $3 per ton to Lake Erie ports. The "wild" and "daily" rate in 1897 was 55 cents; the contract-rate, 65 cents. From Escanaba it was only 45 cents, and from Duluth 57 cents. Freight has been transported across the Atlantic, a distance of 3000 miles, for a little over $1 per ton. This obliteration of distances by steam-power has altered completely the commercial and even the social conditions of the country. Before the railroad and steamboat produced the industrial unification of the continent, not only were food and clothes the product of local and domestic manufacture, but such a necessary article as iron was cast in small furnaces or reduced in small bloomeries, wherever iron-ore and charcoal were found, even in limited quantities, near a water-power. To transport either fuel or ore for any distance over bad country-roads to large establishments was less economical than to run the village furnace or forge. In 1840, therefore, 804 furnaces and 797 bloomeries and forges were scattered over the land to the very outskirts of civilization in Michigan and Wisconsin. Soon after that date commenced the concentration of raw material and the shifting of the centers of the iron-industry to a few favored localities. The process has continued ever since, to the serious detriment and even destruction of some of the older mining and metallurgical districts, and the creation of prosperous communities in what was, a generation or two ago, an inac-

cessible wilderness. Ore and fuel need no longer occur in natural juxtaposition: ore from the Mesabi range can be transported 50 miles by railroad; transferred to boat; carried 800 miles by water; re-transferred to cars, and delivered at so low a figure at Pittsburgh that, when turned into iron and steel by the aid of mechanical appliances, steel rails can be made from it that have been sold at $17 per ton. It is less than a generation since Bessemer rails, made by the same process, but out of costlier ores and by cruder appliances, cost $120 per ton. In very truth, so obedient have the forces of nature become to the will of man that weight and distance, which were, in the days of hard labor and horse-carts, controlling considerations, are being well-nigh eliminated from the calculations of modern engineers.

It would lead us far afield to carry the comparison between the past and the present into the domain of metallurgy itself. But I cannot refrain from drawing your attention to the fact that the 804 old furnaces of 1840, making one ton a day of pig-iron apiece, turned out but little more iron than one of the big Duquesne stacks of to-day—and that our present gigantic pig-iron industry is represented by less than one-quarter the number of furnaces in blast in 1840.

Cheap transportation has not affected the iron-industry alone. It has made it possible to utilize the copper- and lead-ores of the West, and to reduce the cost of their treatment, by taking advantage of neighboring natural facilities. For instance, the Anaconda Co. transports its ore for a few cents from Butte to water at Anaconda, 38 miles distant; and it is advantageous to carry Boston and Montana ore over 176 miles to water-power on the Missouri river. But the very romance of transportation was reached in the following instance: matte was bought at full price in Tennessee; transported by rail to Norfolk, Va.; then shipped to Tampico, in Mexico; carried half-way across that Republic; saturated with gold and silver; concentrated into black copper, and brought back by rail and water to New Jersey for electrolytic treatment! Everywhere the same wonderful interchange of products and transfer of energy from one part of a land to another, or from one country to another, is being effected by the same agencies, thus making the whole world kin, and more or less interdependent as well as independ-

ent. With further improvement in motive-power by land and sea, the present cost of transportation, low as it is, will be steadily reduced, until the day will come when the natural resources of every land will be the common property of the whole world. Already the great German iron and steel plants of Stettin rely entirely on imported crude material. England, Germany and France draw most of their supply of iron-ore from foreign lands. Even we ourselves do not depend altogether on home supply. And when we review the world's resources, we must be convinced that the quantity available within economical reach is so enormous as to preclude all risk of failure from the exhaustion of raw material or of the acquisition by any one country of a monopoly of manufacture. In the north of Sweden, within the Arctic circle, are iron-ore deposits of phenomenal size. That of Gellivave is already connected with the Baltic by a line of railroad; but it is small compared with that of Luossavaara, in which about 215,000,000 tons of iron-ore of very high grade are exposed above the water-line.*

On the shores of Hudson Bay and of Newfoundland large deposits of iron-ore occur, which are not excluded by ice for a much longer period of the year from the market of the world than are ours by like obstacles from our own market. When our canals shall have been enlarged, or new ones shall have been built, Lake Superior ores may find their way to European furnaces almost as cheaply as to Pittsburgh. California has drawn coal from New South Wales and sulphur from Japan. England depends largely on New Zealand for her fresh mutton; and our wheat, beef and pork feed the population of the world. Thus nature's commodities, now that we are learning how to control and use nature's forces, are becoming the common property of all mankind. If that be so, and if the world's resources are in the future to become more and more cosmopolitan, the race for industrial pre-eminence will not necessarily be to those who possess within their own national domain the crude materials for workmanship, but to those who by native wit and scientific learning and acute research can, out of the crude material, manufacture, most cheaply and of best quality, just what the world at large wants. And therefore, if

* Lundbohm, *Iron-Ore Fields of the Province of Norrbolten, Stockholm*, 1898.

certain groups of the world's inhabitants progress more rapidly than others, it will not be altogether or primarily because they possess an undue share of nature's material gifts, but because they evince more aptitude in availing themselves of the opportunities which nature offers them.

Our own industrial growth has excited the wonder of the world. As already pointed out, this growth has been rendered possible by the machinery of transportation and of intelligence, the discovery and extraordinary application of which have been the key-note of the century's progress. Nevertheless, we must admit that it would not have been so rapid and so far-reaching in its influence, had the nation not possessed within its own boundaries natural resources as extraordinary for their diversity as for their quantity. In addition to these advantages, political and social forces have concurred in facilitating our growth. Only two generations have passed since the era of our rapid industrial advance began. Since then we have been able to draw on the untouched resources of a whole, marvellously rich continent. Never in the history of mankind have so many favorable causes combined to assist the industrial development of a people. During the first half of the century, few sordid distractions withdrew our energies from the greatest task a people can undertake—the creation and consolidation of a system of popular government. With the establishment of this on a firm basis, the discoveries of modern science and technology coincided. Thus a free nation was enabled to turn to account its splendid resources with the aid of appliances and natural forces which were contemporaneously and for the first time being brought under the control of mankind. Yet, for all that, had there not been certain qualities in the national character, or, perhaps, to speak more accurately, in the spirit of our industrial classes, these bounties of nature would have remained hidden or neglected.

When we try to analyze the social influences which have been, apart from the natural advantages of this country, the impelling causes in bringing about its rapid rise in the industrial scale, certain differences which distinguish the conditions existing here from those of the older industrial centers of Europe are very conspicuous. Labor, generally superabundant abroad, has here been scarce, and therefore dear. To this

cause is, in part, though not altogether, attributable our substitution of machinery for hand-labor in every department of life. The irrepressible ingenuity of the New Englander, from the time when his high-pendulum clock forced its way into every homestead of the continent, made him an inventor; and his mechanical spirit influenced the whole community as keenly as his republican proclivities helped to model the country's constitutional form of government. It has become a guiding and controlling principle with every American that it is more economical to use your wits than your hands, whether in the kitchen or the workshop; that nature's forces are less easily exhausted than your own; and that iron and steel can stand a heavier strain than human bone and sinew. Acting on this principle, whenever machinery can be made to do man's work, the instinct of the American is to devise some means of bringing this substitution about. When scarcity and the high cost of labor made labor-saving machinery a necessity, this trait of the national character found full scope for its exercise, and the necessity was abundantly satisfied. The result is that more work is done with a given expenditure of manual labor in this country than in any other. The material of which our buildings are erected is hoisted into place by machinery, and we are hoisted into our offices by machinery. We make watches by machinery for a few cents apiece, and locomotives for as few thousand dollars. The ore for our furnaces is mined by machinery, transported to the mills by machinery, hoisted to the furnace-top by machinery, and dumped into the furnace by machinery. By machinery the liquid product is carried to the converter, blown by machinery into steel, and the steel, by a continuous mechanical operation, is wrought into manufactured shapes and loaded on the cars. Half a century ago, to make iron in the small furnaces then in blast, at least six days' labor was expended for a ton of pig-iron alone. To-day, in some of our iron-mines, 4½ tons of ore is the tale of a man's daily work. In the large steel-works, the product of the blast-furnace department is 3½ tons of pig-iron, and that of the whole manufacture is 2 tons of finished steel, made from the ore, per man employed, including the clerical force. In the field of copper, the impulse set by the iron-master has reacted on the more sluggish copper-metallurgist. Instead of the small brick cupola,

in which, 30 years ago, it was thought a notable feat to melt 10 tons a day, furnaces are now running which consume from 400 to 500 tons of ore per day, and discharge their valuable contents into Bessemer converters, which blow it into pure copper in as few minutes as it used to take days to roast and re-roast and fuse and re-fuse the ore, when the cupola-process of reduction was employed. Machinery has not so completely taken the place of the furnace-man in our copper-works as in our iron- and steel-mills; but every year witnesses a steady advance in that direction; and to-day, ore mined in the morning can be loaded as copper into the cars by evening. A secondary but important effect of the extended use of machinery is the necessity which it forces on the manufacturer of producing large quantities. Take, for instance, the Bessemer converter as applied to copper. The smallest converter which can well be used economically will make from 1,000,000 to 1,500,000 pounds of copper per month from a 45 to 50 per cent. matte. If, therefore, this limit be reached, any increase of plant almost compels a doubling of the output—which would bring the production of such small works up to the total for the whole country in 1870.

Machinery is, of course, used the world over; but it is nowhere so generally applied to all purposes of life as by ourselves, nor is it elsewhere forced, by the ingenious arrangement of parts, and by urging it up to its full capacity, to do an amount of work equal to what we demand of it. It is in this respect that American practice has become conspicuous. While the character of the material we have to work upon in our steel-mills doubtless assists the manufacturer, it is mainly by improving the mechanical appliances and the arrangement of the plant that a Bessemer converter, as designed by Holley and other steel-workers, has been made to do so much more than the same apparatus can effect in Europe. Here, automaticity and quantity are the desiderata, and it is justly our boast that we have been able to secure them without impairment of the quality of the product. Yet, great as has been the advance already made, no iron-master considers that the goal has been reached. It must be admitted that our technical workers have made no such important new application of metallurgical prin-

ciples as the Bessemer process* or the Siemens-Martin process, nor were they even the first practically to apply the pneumatic method to the concentration of copper; but, once a valuable invention, no matter where or what its origin, has been introduced, it is applied here with an almost reckless *abandon*, and driven to do our work at a speed almost appalling.

This elimination of manual labor is undoubtedly exerting both an elevating and a depraving influence on our working-classes. The handling of machinery requires, in some vocations, a keener intelligence than the manual use of tools. The engineer of a steam-hoist brings into play a set of faculties very different from those exercised by the men toiling at the handles of a windlass. The gunner on a modern man-of-war must be a mathematician as well as a sailor. On the other hand, the effect of repeating, day in and day out, the same series of manual operations, in keeping up with the unvarying speed of a machine, tends to reduce the man to the level of the machine itself, and must have a most benumbing effect on the faculties. The all-round mechanic of former days is rapidly becoming extinct.

In many respects, however, our rivals in trade are handicapped, and it is fair that we should take only that credit which we really deserve. In this country, few local ties bind the employer and the employed. In the old world the case is different. There certain branches of manufacture have been planted for generations in the same locality. The business has been conducted by the ancestors of the present owners, and the work has been done by the ancestors of the present operatives; and there has grown up a certain sense of joint interest, if not common ownership in the works. This makes difficult the introduction of modern methods and of modern machinery, which, to say the least, necessarily involves a dislocation of old associations. In the famous Krupp works at Essen, for instance, the house, not bigger than a hut, in which the founder of the famous firm lived, is preserved as the nucleus of the existing

* This remark is not intended to ignore the claims of Kelley as an inventor. But it must be conceded that Bessemer's work inaugurated the active development of the method; and the point I am here concerned to make is equally creditable to American genius, which really conferred upon Bessemer's work a new and overwhelming commercial importance.

wonderful mill, as sacredly as though it were the sanctuary of a temple. In going through the plant, I observed that the Bessemer converters were idle. All the steel was being made in the open-hearth furnaces. I asked my guide what had become of the Bessemer workmen. He said they were being employed on buildings for a new colony. I, not unnaturally, observed that steel-workers must prove unhandy operatives at any other craft; but my guide replied that Mr. Krupp never discharged a faithful man, if it were possible to find temporary employment for him in some other department. Such a sentimental motive seldom influences our great employers of labor; and our independent workmen would despise as unbusinesslike such a procedure. The absence of such sympathy, and the latitude it allows to our manufacturer to do what self-interest suggests, materially aid in introducing economies which (at any rate, temporarily) give him an advantage over his European competitors. Abroad, this bond is so strong between the owners of old works and the descendants of the ancestral workmen, that I know of one large establishment in Britain which is anxious to introduce modern appliances, involving a change in methods so radical as to require the discharge of a very large number of its old hands; but the odium and opposition incurred by doing this in the home of the old industry would be so intolerable that, rather than face them, the old works will probably be completely abandoned, and new ones will be erected in a distant portion of the kingdom.*

It is difficult for us to appreciate such obstacles to change and progress; and yet, at the same time, one regrets that before the inexorable claims of modern mechanical progress, the fine family feeling of co-partnership, in which such obstacles originate, should be crushed. And, looking beyond the present, we must perceive that on the solution of these difficult and obstinate problems the advance of some over others of the great industrial communities of the world in the twentieth century will depend.

I wish to draw your attention to another point of difference between ourselves and our competitors which you in the West

* It is not easy to see how this device would really benefit the workmen in the old locality, since it would throw out of employment not merely a part, but the whole, of them. I think Mr. Krupp's method superior.

will appreciate more vividly than does the Eastern technologist. I refer to the advantage conferred, up to a certain point, upon our practical miners and metallurgists by relative technical ignorance, and the consequent freedom from that prejudice and prepossession which a prolonged and exhaustive preliminary education may engender. No doubt, such an education creates in some minds so great a reverence for the past as to cripple the inventive faculty and make its possessor an actual slave to the schools. Even when it does not exert so prejudicial an influence, the scholar is predisposed to follow precedent, and to reject innovation. The lack of it has, up to a certain point, helped the West. Our Western mining regions, for instance, certainly would not have been developed by thoroughly trained geologists as rapidly as they have been by our prospectors, whose more audacious, though less discriminating, enterprise has led them to attack the supposedly impossible. The notions of the prospector may be as positive, as tenaciously held, and as vehemently expressed, as the hypothetical views of the most profoundly educated theorist; but they are based on much more empirical grounds, are deduced from local observation, and are more elastic in their application. In pursuing them he looks for ore, and sometimes finds it, where no cautious expert would dream of seeking it. So many of our Western ore-deposits refuse to conform either to the natural classification under which the students of Europe have arranged mineral bodies, or to the system which our legislators had in view when they composed the U. S. mining laws of 1866 and 1872, that it is well that we possess a corps of sanguine and courageous prospectors, who, being a law unto themselves, have often found mines where, judging by past experience, no mine should have existed.

When we view the progress of metallurgy from the same standpoint, the independence of our metallurgists is seen to be a prime factor in our progress. Even in this art, which depends for ultimate success not only on careful manipulation, but on exact chemical knowledge, some of the most heroic departures from settled practice would hardly have been made by men trained in the older schools. It was under the teaching of necessity, for instance, that, in the '70's, at the first works at Clifton, Arizona, the Messrs. Lezinsky came to build their

copper-furnaces of copper troughs through which water flowed. In the early days of the · ..' '·:. ·'\· '-. one of our most eminent metallurgists denied the possibility of smelting sulphuretted ores in direct contact with a sheet of iron, and, before he would venture to insert a charge, carefully lined the shell with firebrick. When he blew out, no firebrick remained.

As a rule, however, our metallurgists have been men not only of technical skill, but also of learning. Where they differed from their brethren abroad was in their inoculation by the spirit of adaptiveness which is so strong a feature of the national character.

But the technical manager of works is helpless, be he never so progressive, unless his business principals give him a free hand. In this respect, fortunately, few American metallurgists have had reason to complain; for, whether our large mines and works are controlled by corporations or by firms, the business management generally vies with the technical in anxiety to lead in the race of progress, let the improvements cost what they may, or however overwhelming be the apparent sacrifice of old plant. The individual or corporate owners of the great enterprises with which we are associated as technical advisers are generally as radical in their willingness to depart from the older methods as we are ourselves. They are as free from the shackles of precedent as their expert employees—a point of great importance in estimating the conditions of our future struggle with our competitors.

We shall, however, commit a grievous mistake, if we imagine that the reaction of our example upon Europe will not be as sensitively felt as the past influence of Europe has been felt by us in the past. Therefore, the lesson I wish to draw from the preceding general survey is, that the industrial standard of a nation in the twentieth century is likely to be determined more by its capacity for progress than by its mere possession of crude natural resources. Not only the world's primary supplies, but also the world's technical experience, are becoming more and more the heritage of all; and consequently the lead will be taken by the nation whose technical managers possess skill, stimulated and not stunted by education, and so directed as, by elevating the intellectual condition of its operatives, to prevent them from sinking to the level of mere cogs in the wheel of a soulless industrial machine.

Cyaniding in New Zealand.

BY JAMES PARK, THAMES, AUCKLAND, N. Z.

(California Meeting, September, 1899.)

Apart from three or four small plants for the treatment of tailings in the South Island, there is no cyaniding of any moment in New Zealand, outside the Hauraki gold-fields in the province of Auckland.

The Hauraki peninsula is about 85 miles long, and varies from 4 to 20 miles in width. The surface is very broken and everywhere densely wooded. The principal physical feature is a rugged axial mountain range, running in a somewhat sinuous course from one end of the peninsula to the other. It varies from 1200 to 3200 feet in height, and forms the main divide or watershed, from which innumerable subsidiary ranges or spurs, generally bold and precipitous, descend to the sea on both sides.

The average yearly rainfall is about 52 inches; and although the configuration of the peninsula forbids the existence of large rivers, there is no lack of small never-failing streams, which, as sources of power, make up for their deficiency in volume by the steepness of their descent.

Except at the Thames and Coromandel, the mining camps are much scattered, and owing to bad roads and tracks, communication between them is not always easy, particularly in the wet season.

Geological Conditions.

The principal gold-bearing formation is of volcanic origin, consisting of a great accumulation of andesitic lavas, tuffs, breccias and agglomerates of lower Tertiary age. These rocks everywhere bear evidence of having been subjected to the prolonged leaching-action of thermal waters, doubtless accompanied by steam and acid vapors. They are found in all stages of decomposition or alteration; and in many mines the hard blue andesite can be seen to pass by a series of almost insensible gradations into a soft, or fairly hard, greyish yellow or blue

altered rock to which the distinctive name propylite has been applied.

It is in this altered andesite that the veins yielding pay-ore occur. They vary from a few inches to 40 feet in width, but in linear extension they can seldom be traced for any considerable distance. The ore-values are also irregular, and in no case is the same vein or lode worked with profitable results in two adjoining mines.

Treatment of Ores by Amalgamation.

In the northern gold-fields the ores, with a few exceptions, are free-milling, consisting for the most part of greyish-blue crystalline quartz which generally carries a proportion of pyrites ranging from 0.5 to 2 per cent. The gold is alloyed with silver to the extent of nearly one-third, its average fineness at the Thames being .680, and at Coromandel .760; but in most mines the fineness is subject to great variation, and even in the same lode the value will sometimes vary several shillings per ounce within the height of a stope. The gold occurs both in leafy plates and in the form of a fine pepper-like dust scattered through the stone. It seldom exists in the sulphurets; and it is a matter of universal experience that in the battery-tailings, the values lie principally in the coarse sands.

In a pay-ore, which means anything over 5 dwts. per ton, "colors" of gold are plainly visible in the stone; and conversely, an ore in which no gold is visible to the eye is seldom or never pay-ore.

These ores are treated by wet-crushing, plate-amalgamation* and blanket-concentration. The tailings are concentrated in Cornish buddles, and, if they contain a value of 2 dwts. or more per ton, are ground and amalgamated in Watson-Denny, MacKay, Fraser or some other pattern of continuous-overflow pan. The blanketings are ground and amalgamated in Berdan pans.

During the last quarter of 1898 we treated, at the May Queen Co.'s old 32-stamp mill, 723 tons of ore of this class for the Company and 613 tons for tributers, at a cost of 4*s*. 11.94*d*. per ton of 2240 pounds, made up as follows:

* In most mills muntz-metal plates are used in preference to copper plates. The ore is generally very "sour;" and it is found easier to keep muntz plates in good condition.

	Total Cost.			Cost per Ton.	
	£.	s.	d.	s	d.
Wages and management, ...	203	10	11	3	0.56
Foundry account, ...	20	3	4	0	3.62
Store "	17	6	4	0	3.11
Water "	85	4	3	1	3.31
Firewood "	7	9	6	0	1.34
Total, ...	£333	14	4	4	11.94

The cost per short ton of 2000 pounds would amount to 4*s.* 5.53*d.* The foundry-costs are for steel shoes and dies for stamps at 18*s.* per cwt., and cast-iron shoes and liners for pans and mortars at 13*s.* per cwt. The store-costs include the supply and delivery of wire-wove screens and quicksilver, also oil, waste, and other sundries.

At the same mill we have recently crushed and treated 906 tons of ore for the Company's tributers at a cost of 6*s.* 2.3*d.* per ton, made up as follows:

	Total Cost.			Cost per Ton.	
	£.	s.	d.	s.	d.
Wages and management, ...	172	8	6	3	9.67
Foundry account, ...	21	17	7	0	5.79
Store "	11	0	11	0	2.93
Water "	65	9	7	1	5.34
Firewood "	9	14	0	0	2.57
Total, ...	£280	10	7	6	2.30

This result, calculated per short ton of 2000 pounds, would be 5*s.* 7.44*d.*

The increase of milling-costs in this case was due to the fact that the 906 tons of ore were treated in 94 separate parcels, each parcel necessitating a separate "clean-up." The large number of retortings explains the heavy cost of firewood, which is supplied at 11*s.* per ton.

At the Moanataiari 60-stamp mill, for a somewhat similar ore, I tried, for a time, plate-amalgamation, followed by close concentration with vanners, and buddling of coarse sands. But after a few months' run this experiment was abandoned as unprofitable, principally on account of the low grade of the ore and resulting concentrates, and the high cost of cyaniding the latter. Subsequently the vanners were run so as to collect the coarse sands as well as the sulphurets, giving a product resembling the blanketings at the May Queen, which was afterwards ground and amalgamated in pans.

The treatment by this method of 576 tons of high-grade ore, lately finished, gave a recovery of gold amounting to 82.51 per cent. of the assay-value.

	£.	s.	d.
576 tons at £3 5s. 6d. per ton, ...	1886	8	0
Gold recovered (555 oz., 17 dwts.), ...	1556	9	4

	Per Cent.
Plates, ...	51.67
Coarse concentration, ...	30.84
Total, ...	82.51

The 576 tons of general ore yielded 85 tons, or 14.75 per cent. of coarse concentrates, having a value of £9 4s. 6d. per ton, giving a total value of £784 2s. 6d., of which 86.11 per cent. was recovered by pan-amalgamation at a cost of 5s. 5d. per ton for quicksilver, water, labor, etc.

The crushing-, milling- and amalgamating-costs of the general ore and concentrates amounted to 6s. 10.78d. per ton of 2240 pounds; or 6s. 0.12d. per ton of 2000 pounds, as below:

	Total Cost.			Cost per Ton.	
	£.	s.	d.	s.	d.
Wages and management, ...	113	7	5	3	11.23
Store account, ...	23	18	4	0	9.97
Foundry "	7	4	0	0	3.00
Water "	54	4	1	1	10.58
Total, ...	£198	13	10	6	10.78

The treatment of the concentrates consumed 92 pounds of quicksilver, thus accounting for half the cost under the head of store account.

Treatment of Ores by the Cyanide Process.

In the southern portion of the peninsula the pay-ores consist of whitish-grey chalcedonic or crypto-crystalline quartz, often possessing a wavy, banded structure of alternating layers of grey and blue flinty quartz. They are comparatively free from base sulphurets.

The gold is about .645 fine and usually associated with silver sub-sulphide (Ag_2S) in varying proportions. It is generally extremely fine, being seldom visible to the eye; and, in the great bulk of the Waihi ore, it is impossible to get even a "color" by panning.

Dry-Crushing.

Prior to the introduction of the cyanide process these ores were treated by dry-crushing and hot pan-amalgamation with chemicals, by which a recovery of 65 per cent. was effected.

When cyanide-treatment was adopted, dry-crushing was naturally continued at the different mills, the dry pulverized material being charged into shallow vats and treated directly with cyanide. From 65 per cent. by pan-amalgamation, the recovery rose at a bound to 85, and in some cases to 90 per cent., and the results were so satisfactory that no further improvement was considered possible.

In a few years, however, it became apparent that dry-crushing possessed many disadvantages, as compared with wet-crushing, the principal ones being the cost of the preliminary drying of the ore, the low duty of the stamps, and the large number of vats required for leaching. In 1897, mine-owners began to turn their attention to wet-crushing; and one by one, since the beginning of 1898, the different mills have been adopting wet-crushing, until, at the present time, dry-crushing is the exception and not, as it was two years ago, the rule.

The practice of dry-crushing, as carried on at the Waihi Co.'s mills, although not an example to be followed, may be of some interest to members, if only for comparison with the results obtained by wet-crushing.

Drying the Ore.—The ore is dried in brick-lined kilns, which consist of open circular holes excavated in the solid rock. The kilns at the old 90-stamp mill were 37 feet deep and 20 feet in diameter, their capacity being about 100 tons. At the new 100-stamp mill, the kilns hold a charge of 500 tons each. The lower part of the kiln is finished off with a brick arch, having a door and an iron chute for discharging the dried ore into trucks, which have access to the kiln by means of a tunnel.

The kilns are charged with alternate layers of ore and wood, the layers of wood being about 5 feet apart. When the kiln is fully charged, the wood is lighted; and, after it is all burned up, about half the charge is withdrawn and an equal portion of raw ore is added on top, together with the necessary firewood. When this second charge is burnt the lower half of the charge is withdrawn and another charge of ore and wood added on the

top. Thus the successive charging and drawing off is carried on continuously.

This method of drying has very little to commend it, and possesses many serious disadvantages, of which the most obvious are: (1) the high cost of fuel and labor; and (2) the risk of unconsumed charcoal remaining in the ore. In the case of pyritic ore, the varying temperature to which the ore is subjected, especially in large kilns, also tends to have a pernicious effect. For it is certain that, where the temperature is high, reducing gases must be evolved, and that these in turn would impede the oxidation of the sulphides, causing the formation of lower sulphides and basic sulphates which react injuriously on the cyanide solution.

At the other dry-crushing mills in New Zealand, automatic revolving dryers are used, the consumption of fuel being only about one-quarter of that in the open kilns.

Crushing and Pulverizing.—The dried ore is trucked to the stamp-mills, passing first through a No. 5 Gates crusher and thence through a trommel, the coarse material falling automatically into a No. 3 Gates. From the crushers, the ore is trucked to bins, lined with sheet-iron as a precaution against fire.

The stamps weigh from 900 to 1000 pounds, and drop from 103 to 105 times per minute. The height of drop varies from 7 to 8 inches. The ore is crushed through 30- or 40-mesh wire-wove screens, the duty of the stamps varying from 1.5 to 1.7 tons of 2240 pounds per day.

The dust-nuisance, which at one time was intolerable, is now kept down by an exhaust air-pipe, with which each mortar-box is connected. The dust is caught in a dust-chamber, and from time to time collected and mixed with the general ore. It is a somewhat curious and interesting circumstance that the finer the dust the higher its value.

At my request Mr. E. G. Banks, the Company's metallurgist, sampled and valued the dust that had settled on the rafters and timbers of the mill-house, with the following results:

		Value per Ton.		
		£.	s.	d.
A.	Dust from floor of mill to 10 feet high,	6	16	4
B.	" " 10 feet to 20 feet high,	7	2	4
C.	" " 20 " 30 " "	7	3	1
D.	" " 30 " 40 " "	7	19	11
E.	" " 40 " 60 " "	8	13	8

The average value of the ore from which the dust was obtained was £4 1*s.* 4*d.* per ton.

Conveying the Pulverized Ore.—At the old mill the pulverized ore is conveyed to storage-hoppers by means of screw-conveyors. From the hoppers it is trucked to the leaching-vats. At the new mill a long line of screw-conveyors carries the dry pulp direct to the vats.

The Cyanide-Treatment.—At the old mill there are 32 wooden vats, 22.5 feet in diameter and 4 feet deep, with the necessary sumps, tanks, extractors, etc. At the new mill there are 10 rectangular concrete leaching-vats, 50 feet by 40 feet in area, and 4 feet deep.

The wooden vats hold a charge of 30 tons, and the concrete vats of 150 tons each. The depth of the charge in each case is about 24 inches. With a greater depth of material the difficulties attending percolation became too great for economical working.

After the charge is leveled, the strong solution, containing from 0.33 to 0.4 per cent of cyanide, is run under the filter-cloth until it shows on the surface of the pulp. The balance of the solution is then run on top of the charge. The portion of solution remaining below the filter is also pumped on top.

The strong solution (in the proportion of 1 to 3 of ore) is allowed to percolate for 30 to 40 hours. The weak solutions (1 to 3 of ore, and containing 0.1 to 0.03 per cent. of KCy) and the water-washes are then applied in rapid succession, their filtration being assisted by an artificial vacuum of 20 to 25 inches of mercury. Each ton of ore gets washed with one ton of water in four separate portions.

About 5 days are required for the washings, and the total treatment of each vat occupies about 6.5 days.

The residues are sluiced out through side-doors, one man emptying 150 tons in 8 hours.

The solutions from the leaching-vats are clarified by running them through tow filters, whence they pass to the zinc-extractor boxes, which are of such a capacity that 1 cubic foot of zinc is provided for every ton of solution per day.

The consumption of cyanide varies from 2 to 2.5 pounds per ton of ore treated, and that of zinc is about 6.5 ounces, costing 5*d.* per pound.

The drying and smelting of the slimes call for no special notice.

I am indebted to Mr. Banks for the following schedule of costs:

Milling-Costs per Ton.

	s.	d.
Drying the ore, labor and fuel,	1	0.60
Crushing, including maintenance,	1	3.34
Stamping, including maintenance,	1	10.69
Total,	4	2.63

Cyaniding-Costs at New Mill per Ton.

	s.	d.
Wages of labor,	0	4.46
Cyanide,	2	0.00
Zinc,	0	2.00
Filter-cloths,	0	0.70
Clean-up and smelting of slimes,	0	4.10
Total,	2	11.26

The total cost of milling and cyaniding is 7*s.* 1.89*d.* per ton, not including management and general expenses, which are not given.

The last monthly output was 7715 tons, yielding 21,974 ounces of bullion, valued at £24,244·1*s.* 3*d.*, equal to a value of £1 2*s.* 1*d.* per ounce.

The actual recovery is reported by the management to be 89 to 90 per cent. of the gold, and 55 to 60 per cent. of the silver, from ore ranging from £3 10*s.* to £4 per ton.

For a year or more bunches of high-grade pyritic ore have appeared in the lower levels of the Company's celebrated Martha lode, and, with increasing depth, will probably become more abundant. It has been found that the treatment of this ore by dry-crushing is not successful, on account of the partial roasting occurring in the kilns, and resulting in the formation of basic sulphates, etc., which cause a large consumption of cyanide, accompanied by low extraction. Wet-crushing and concentration of sulphurets, followed by cyaniding of sands and slimes, naturally suggest themselves as the proper treatment; and experiments in that direction are now being made at the old mill.

At the other dry-crushing mills on these gold-fields, the milling- and cyaniding-practice is practically the same as at Waihi, except at the Whangamata Proprietary, where the ore is pulverized by ball-mills, and at Talisman, where both stamps and ball-mills are used. In all cases the ore is dried in revolving dryers, the use of which results in a great saving of cost of both labor and fuel. At the Talisman mill, 1 ton of firewood dries 12 tons of ore, while the consumption of the same amount of wood is required to dry only 3 to 4 tons of ore in the Waihi open kilns.

Wet-Crushing.

A. For ores containing a large proportion of free, easily amalgamable gold, with a small proportion of fine or "float-"gold and silver sulphide, the mill-practice is:

a. Crushing with water.

b. Plate-amalgamation.

c. *Spitzlutte*-separation of sands and slimes.

d. Cyanide-treatment of sands and slimes by ordinary percolation.

A typical example of an ore of this class is that of the Kauri Gold Estates at Opitonui, where a new 40-stamp mill has just started. The sands and heavy slimes are subjected to the "double" cyanide treatment; but it is doubtful if the additional saving will pay for the extra labor involved. So far, no provision has been made for the treatment of the fine slimes. If they are worth it, they will probably be treated by agitation and decanting.

B. For a clean ore, almost identical with that described above, but containing a small proportion of free amalgamable gold, and a large proportion of fine cyaniding-gold, with little or no slimes, the method of treatment at the Crown mines is:

a. Crushing with cyanide-solution.

b. Direct cyanide-treatment of mixed sands and slimes by percolation.

c. Plate-amalgamation of free gold.

With an ore so exceptionally free from slimes, it seems that the order of treatment could be reversed with advantage, as regards both stamp-duty and efficiency of amalgamation on the plates.

The Crown Mines Co. was the first (in 1897) to adopt wet-crushing for these gold- and silver-bearing chalcedonic ores; and much credit is due to Mr. F. R. W. Daw, the superintendent, for its successful inauguration.

The ore is hard and splintery, clear and free from all impurities, and, unlike most of the ores from the neighboring mines, contains little or no silver, except what is alloyed with the gold. It is crushed in the Co.'s 60-stamp mill with cyanide-solution in the mortars, about 2.5 tons of solution being used to 1 ton of ore. A 25-mesh screen is used, and the duty per stamp is about 2 tons per day. The slimes formed in crushing are said to amount to less than 5 per cent. The monthly output is about 2750 tons. In the month of June last, 2900 tons were crushed, yielding 3037 oz. 5 dwt., of bullion, valued at £6069 14*s*. 8*d*., equal to a fraction under £2 per ounce.

The cyanide-plant consists of 28 leaching-vats, each 22.5 feet in diameter and 4 feet deep. Much reticence is maintained as to the exact treatment; but the main features are understood to be as follows:

The whole of the pulp from the 60 stamps is conducted by a launder to one vat, and allowed to discharge into the center until the vat is about half-full. The pulp is then diverted to another vat, which is allowed to fill in the same manner. The mixed sands and slimes in the first vat are allowed to settle for an hour or two, after which the fairly clean top-solution is syphoned off into a collecting-tank, whence it is pumped up to two elevated tanks, from which the solution for the stamps is supplied. The pulp is again diverted into the first vat until the charge is complete. After settlement, the clear top-solution is again drawn off. In this way three or four vats may be in course of filling at the same time.

The settlement of the slimes is effected without the aid of lime by allowing the solution to percolate from the bottom of the vat during the filling and periods of settlement. The downward currents promoted by the draining from below are said to promote the settlement of even the finest material within a reasonable time. This is a point to be noted by cyaniders troubled with slimy products.

The mixed sands and slimes are treated by percolation in

the ordinary way. The depth of each charge is about 30 inches and the weight 40 tons. The strong cyanide solution is allowed to percolate from 30 to 40 hours, while the weak cyanide and water-washes are drawn off by the aid of an air-pump.

The syphon used in the sand-vats consists of a length of 2.5-inch rubber hose, to one end of which is attached a short length of wooden batten, to keep it on the surface of the solution. The other end is fixed, inside the vat, to a short iron pipe passing through the side, about 18 inches above the filter-cloth.

In the extractor-room there are five precipitation-boxes of the ordinary pattern, divided into compartments by baffle-boards; and four zinc-towers, consisting of wooden boxes about 6 feet high and 30 inches square, set on end and connected in a series, like charcoal-towers. The solutions flow upwards through the zinc-turnings, the overflow being conducted in a pipe to the bottom of the next tower, and so on to the last.

The sands are sluiced out of the vats over a wide expanse of amalgamated copper plates, which catch a certain proportion of the free gold.

The actual recovery from all sources is said to vary from 84 to 87 per cent.; but the figures of cost are not obtainable.

C. For ores containing some easily amalgamable gold and fine gold, associated with pyrites and silver sulphides, the treatment used is:

a. Crushing with water.
b. Plate-amalgamation.
c. *Spitzlutte*-separation of fine slimes, if necessary.
d. Vanner-concentration of sulphurets.
e. Cyanide-treatment of sands by percolation.
f. Cyanide-treatment of slimes by agitation and decanting.
g. Cyanide-treatment of concentrates by agitation.

The practice at the Woodstock mill is a typical example of this system, the details being as follows:

The ore is chalcedonic and finely crystalline quartz, containing a small proportion of clayey matter and a little pyrites. It is stained a greyish and blackish brown color through the presence of iron and manganese oxides.

At the Co.'s 40-stamp mill, the monthly output is about 1100 tons, the stamp-duty being slightly under 2 tons of 2240 pounds per day. In June last, 1000 tons of ore were crushed, with a return of £1362, or £1 7*s.* 6.68*d.* per ton. The value of the bullion varies from 8*s.* to 12*s.* per ounce, being principally composed of silver.

The ore is crushed with water and passed over amalgamated copper plates, from the end of which the pulp is raised by a wheel-elevator to a *Spitzlutte*. The slimes from the *Spitzlutte* are conducted to a slime-tank, while the sands, carrying some heavy slimes, are passed over vanners, which collect about 1 per cent. of rich concentrates.

The vanner-tailings, composed principally of sands and heavy slimes, are led to the leaching-vats, which are provided with automatic distributors. The construction of the distributors is of the simplest character, being similar to that of those formerly used at Waihi. They consist of a central wooden box, pivoted on a wooden pillar fixed in the center of the vat, and from which extend seven light narrow wooden launders, or arms, of different lengths, so as to effect an even distribution of the pulp. At the end of each arm is fixed a piece of sheet-zinc to divert the stream to one side.

The whole of the pulp from the vanner-ends is collected in one stream and diverted into one vat at a time, until the charge is filled. During the filling, the overflow carries the lighter slimes into the slime-vats.

The sands and heavy slimes are treated with cyanide by ordinary percolation.

The slimes from the *Spitzlutte* and those from the sand-vats are agitated with cyanide in vats provided with slowly revolving arms. When the gold is dissolved, lime is added, and the slimes are allowed to settle; after which the clear solution is decanted off. The slimes are washed by agitating with successive portions of water, and decanting.

The concentrates have a value of £30 to £40 per ton, a large proportion of the value being in silver sulphide. They are treated by agitation with a 4 per cent. solution of cyanide for 36 hours. Two pounds of lime are added to every ton of concentrates. The charge weighs about 1.5 tons. Mr. Frank Rich, the superintendent, who adopted the present treatment,

informed the author that the recovery varied from 90 to 94 per cent., at a cost of 18*s.* per ton for labor and material.

The recovery by cyanide from all sources is said to vary from 82 to 86 per cent., at a cost of 4*s.* 9*d.* per ton of ore milled.

D. For very slimy ores, containing very little easily amalgamable gold, and a large proportion of extremely fine gold, besides the usual silver sulphides, the treatment is as follows:

a. Crushing with cyanide solution.
b. *Spitzlutte*-separation of sands and slimes.
c. Treatment of sands by percolation.
d. Treatment of slimes by agitation and decanting.

This method of treatment is subject to various modifications, as regards mechanical appliances and methods of application; but the general principles are the same everywhere.

The procedure at the Waitekauri 40-stamp mill is as follows: The ore, which contains a good deal of oxidized products, is crushed with cyanide solution in the mortars. From the screens the pulp is conducted direct to the sand-vats, into which it is distributed by means of revolving wooden box-launders, actuated from a secondary shaft. The slimes, amounting to about 33 per cent., are allowed to drain into a collecting-vat, flowing through a pipe fixed in the inside of the vat. This pipe has a movable joint, and is raised by a screw as the pulp accumulates in the vat.

The collecting-vat is provided with revolving arms, which keep the fine slimy pulp from settling. From this vat the slimes are pumped into the slime-leaching vats, which are provided with a double set of slowly revolving arms, the lower ones having rakes on them, and the upper ones, loose pieces of sacking which drag through the pulp. In these vats the slimes are treated by agitation and decanting, lime being added with each wash to facilitate settlement.

The sands are treated by ordinary percolation with first a 0.5 per cent. solution of cyanide, and then with the weak solution and water-washes.

There are 12 sand-vats, 14 slime-vats, and 2 slime-collecting vats, each 22.5 feet in diameter and 4 feet deep. The monthly output of the 40 stamps is about 2200 tons of 2240 pounds. The June monthly output was larger than usual, being 2543

tons, yielding 7220 ounces of bullion, valued at £6773 0*s.* 6*d.*, or 18*s.* 9*d.* per ton. The actual recovery is said to be 90 per cent. at a cost of 5*s.* 6*d.* per ton.

The exceptionally large proportion of slimes in this ore rendered the adoption of wet-crushing a knotty problem. The increased output, higher extraction and lower costs are proofs enough of the success of the change from dry-crushing, which was effected under the supervision of Mr. G. Davey, the superintendent, without hitch, or decrease in the monthly output—a matter of no little moment in these days of heavily capitalized public companies.

Concluding Remarks.

Among the points most likely to attract the notice of members are the low stamp-duty and the heavy consumption of cyanide.

The low stamp-duty of the Ohinemuri mills has often been a subject of discussion; but, to my mind, no satisfactory explanation has been advanced. I am of the opinion that it is due to the circumstance that the mills having been designed and erected in the first place for dry-crushing, the mortars are too narrow and restricted to give good results by wet-crushing. Until they have been replaced by new mortars specially designed for wet-crushing, it seems hopeless to look for better results. The advantages of a stamp-duty of 4 or 5 tons per day instead of 2 tons are too obvious to require specification.

Silver in all its forms requires a stronger solution of cyanide to effect its solution than gold; and on these gold-fields the large consumption of cyanide is due to the presence of silver sulphide (principally Ag_2S) generally in amounts worth saving, and to the circumstance that the free gold is alloyed with about one-third its weight of silver.

According to Elsner's equation for the solution of gold by potassium cyanide, 4 pounds of cyanide should dissolve 100 ounces of gold; but in practice it is found that the operation takes nearly forty times that quantity. To dissolve 100 ounces of silver, would require 7.5 pounds of cyanide according to the equation:

$$4Ag + 8KCy + O_2 + 2H_2O = 4(AgKCy_2) + 4KHO.$$

For the solution of 100 ounces of silver existing as the sub-sulphide (Ag_2S), 7.01 pounds of cyanide would be required by the following equation:

$$Ag_2S + 4KCy = 2(AgKCy_2) + K_2S.$$

The potassium sulphide resulting from the dissolution of silver sulphide also tends to cause a loss of cyanide. It has been shown by Crosse and others that a trace of alkaline sulphide in cyanide-solutions does not act injuriously; but the large quantity of K_2S liberated in the treatment of the silver-bearing ores of the Hauraki gold-fields must cause the precipitation of a portion of the dissolved gold in the vats. Much of this precipitated gold is doubtless redissolved by the excess of free cyanide present in the solutions; but it always requires this excess to obtain adequate extractions, thus necessitating the use of comparatively strong solutions.

The cyanide process was first introduced in 1889 at the Crown mines at Karangahake,* a property owned by a Glasgow company which had entered into a contract with the patentees, Messrs. MacArthur and Forrest, to treat the ore. This was the first actual application of the process at a mine. For two or three years the work carried on was largely of an experimental character, and until 1894 the results were unimportant.

For the year ending March 31st last, 45.31 per cent. of the gold and silver raised in New Zealand, amounting to the value of £489,767, was produced by the cyanide process.

At the majority of mines cyanide-treatment was adopted by the owners on the author's recommendation, but only after he had made a careful investigation of the constituents of the ore, and repeated trials on a working scale at the Government experimental works at the Thames. In other cases, the necessary experimental trials were made by the author's assistants at the mine. In no case was the process adopted until success had been assured, a precaution which doubtless has been a potent factor in promoting the popularity of cyanide-treatment in this country.

The ores of Te Aroha and Monowai are generally very refrac-

* For description of works and mode of treatment see New Zealand *Reports on the Mining Industry*, 1890, pp. 38 to 40.

tory, containing free-milling gold, mostly very fine, associated with sulphides of silver, iron, copper, lead, zinc, and often mercury. Many attempts have been made to treat them by cyanide, but without success, and, so far as our present knowledge goes, it is doubtful if they can ever be treated successfully in the raw state by that process.

For the treatment of cupriferous ores and concentrates from the Jubilee, Sylvia and Monowai mines, which could not be treated successfully by ordinary cyaniding, the author obtained good results by first subjecting the ore to a chloridizing roast, and then leaching out the copper chlorides with water. After an alkaline- and water-wash the gold and silver contents were extracted by cyanide by percolation. During the roasting the silver sulphides present were chloridized to the chloride which is easily dissolved by cyanide.

From a large parcel of Monowai ore, 92 per cent. of the gold and 85 per cent. of the silver were extracted, the composition of the ore being determined by Mr. F. B. Allen, M.A., B.Sc., as follows:

	Per Cent.
Insoluble gangue,	90.15
Copper pyrites,	3.78
Iron pyrites,	4.40
Galena,	0.25
Zinc-blende,	0.26
Alumina,	0.13
Water and loss,	1.03
	100.00

The bullion-contents of this ore were: gold, 1 ounce 5 dwts., and silver, 14 ounces, per ton.

One of the most perplexing features connected with the treatment of these ores is the constantly varying proportion of silver, which necessitates the use of solutions of varying strength to obtain adequate extractions, thus adding another source of anxiety to the many worries which the use of cyanide entails on the successful cyanider.

The Temperatures at which Certain Ferrous and Calcic Silicates are Formed in Fusion, and the Effect upon these Temperatures of the Presence of Certain Metallic Oxides.

BY PROF. H. O. HOFMAN, INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

(California Meeting, September, 1899.)

I. INTRODUCTORY.

IN the blast-furnace smelting of lead, copper and other non-ferrous metals, the largest part of the product obtained is slag. Its formation consumes more of the heat-energy of the fuel charged than any other chemical reaction that takes place. It is therefore of importance to know at what temperatures the different slags will form, so as to be able to choose in a given case the slag that will form at the right point in the operation, will keep the products thoroughly fluid, so as to insure a satisfactory separation, and will permit the consumption of fuel to be reduced to the lowest practicable point. While practical experience has brought out in a general way the leading differences as to the formation-temperatures of some silica—iron—lime slags, accurate details are still wanting. The object of the investigation here described was to supply some of these.*

Prominent among the men who have worked on the fusibility of silicates are Lampadius,† Sefström,‡ Berthier,§

* The expenses of this investigation were defrayed by the American Academy of Arts and Sciences from the income of the C. M. Warren Fund for Chemical Research.

† *Journal des Mines*, 1809, xviii., 171; also *Handbuch der Allgemeinen Hüttenkunde*, H. Dieterich, Göttingen, 1801–1810, i., 127.

‡ *Jernkontorets Annaler*, 1828, i., 155; also Erdmann's *Journal für Technische und Oekonomische Chemie*, 1831, x., 145.

§ *Traité des Essais*, Paris, 1834, i., 430.

Percy-Smith,* Bischof,† Plattner,‡ Åkerman,§ Howe‖ and Gredt.¶

In the earlier researches, the criterion of fusibility was the time that a mixture or slag was exposed to a heat, or the furnace in which the experiment was carried on. Bischof, in determining the melting-points of some silicates of iron, lime, magnesia and alumina, used the melting-points of iron and cast-steel for measuring temperatures. Plattner, in working on the formation- and melting-temperatures of some lead and copper slags, used gold-platinum fusion-pyrometers. While his original figures, based upon the calculated melting-temperatures of the gold-platinum alloys, are very much too high, his results become approximately correct if the melting-points of the alloys, as determined by Erhard and Schertel,** are substituted. Plattner used clay, iron and brasqued crucibles, which cannot but have had a decided influence in changing the composition of the mixtures fused in them. Akerman and Howe employed the calorimetric method in their work on iron blast-furnace slags, and Gredt, finally, made use of Seger cones (of which, more later on) in studying the influence of magnesia upon alumina-lime silicates.

The investigation constituting the subject of this paper was begun in 1895 and continued in 1898. The preliminary work was done by Mr. W. C. Powers, a student in the chemical department of the Institute of Technology, and the final work by Mr. A. L. Davis, first as student in the Department of Mining and Metallurgy of the same institution, and then as the writer's private assistant.

II. Materials.

The slags made in smelting non-ferrous metals in the blast-furnace consist mainly of silica, ferrous oxide and lime, the ferrous oxide being occasionally replaced, to some extent, by man-

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* Percy, *Fuel*, London, 1875, 59.

† Dingler's *Polytechnisches Journal*, 1862, clxv., 378.

‡ Merbach, *Die Anwendung der Erwärmten Gebläseluft in der Metallurgie*, Leipsic, 1840, p. 288.

§ *Jernkontorets Annaler*, 1886, p. 1; also *Stahl und Eisen*, 1886, pp. 281, 387; "Graphical Representation," by Howe, *Trans.*, xxviii., p. 346.

‖ *Trans.*, xviii., 724.

¶ *Stahl und Eisen*, 1889, ix., p. 759; Åkerman's *Critique*, *id.*, 1890, p. 424.

** *Freiberger Jahrbuch*, 1879, part i., p. 154.

ganous oxide, the lime by magnesia, baryta and zinc oxide, and the silica and lime by alumina. These compounds, therefore, formed the materials on which the experiments were based.

Silica.—For silica, pure crystallized quartz from Chester, Mass., was chosen. It was ground to pass through a 100-mesh sieve, boiled with nitro-hydrochloric acid until all soluble iron had been removed, and then washed with distilled water until sweet. An analysis gave 99.8 per cent. SiO_2, and the powder was used as if it had been chemically pure.

Ferrous Oxide.—Two methods for obtaining the iron in the ferrous state were considered—the decomposition of ferrous oxalate by heating, and the reduction of magnetic oxide by means of metallic iron.

Ferrous oxalate, $FeC_2O_4 + 2H_2O$, is a lemon-yellow powder, formed upon the addition of oxalic acid to a ferrous sulphate solution, and is an article of commerce. It is stable* at an ordinary temperature even when moist. At 150° to 160° C. it gives up one-half of its water. According to Birnie,† it gives up all its water below 200° C. when heated in a current of nitrogen, and is completely decomposed at 300° C. The reaction does not, as might be expected, quite correspond to the formula

$$FeC_2O_4 + 2H_2O = FeO + CO + CO_2 + 2H_2O.$$

The black residue of ferrous oxide contains 1 to 1.5 per cent. of carbon, and, as a rule, 0.3 to 2 per cent. of metallic iron; and there are five volumes more of carbon dioxide and five volumes less of carbon monoxide than the equal volumes called for by the equation. It was believed (and the experiments proved it) that, if the tests were made in a strongly reducing atmosphere, vitreous slags showing no magnetic property whatever could be obtained. As we, however, did not always succeed in producing an absolutely reducing atmosphere in the crucible, many of the slags formed were more or less attracted by the magnet. They were usually black to brown; occasionally they showed a reddish tinge suggesting a partial oxidation

* Ladenburg, *Handwörterbuch der Chemie*, Breslau, 1890, vol. viii., p. 404.

† *Receuil des Travaux Chimiques des Pays-Bas*, 1883, vol. ii., p. 273; abstract in *Jahresberichte über die Fortschritte der Chemie*, 1883, p. 1045.

of the iron to the ferric state. The luster on a fresh fracture was vitreous to sub-metallic.

The second method, which was used by Berthier* and Plattner,† employs iron scale as the source of iron. The ferrous oxalate was preferred, because it could be obtained as a chemically pure salt, while the analyses of iron scale showed the presence of more or less silica, which would have complicated the calculations. Moreover, there seemed more promise of getting the iron in the ferrous state from a ferrous salt than through the reduction of the magnetic oxide by the use of finely divided metallic iron.

Manganous Oxide, Etc.—For manganous oxides, lime, magnesia and baryta, the chemically prepared pure carbonates were used, and for zinc oxide and alumina the chemically-prepared pure oxides.

III. Measurement of Temperature.

As the aim of the investigation was to determine formation-temperatures, the calorimetric method used by Åkerman and Howe was excluded, as it gives only the melting-points of the formed slags. But even when these are to be determined, the calorimetric method cannot well be used with ferrous slags, owing to the difficulty of finding a suitable crucible-material. A clay crucible is attacked by the slag; an iron crucible is liable to increase the percentage of iron; a brasqued crucible causes some iron to be reduced to the metallic state; and, lastly, a platinum crucible‡ when heated in a smoky flame, is damaged through the formation of a carbide of platinum, which, being oxidized by other parts of the flame containing unconsumed air, becomes covered with blister-like excrescences. Again, at a temperature above 1430° C. (Seger cone No. 15) platinum is attacked by the silicates, a silicide of platinum§ being formed, which is readibly fusible. It is not improbable that some iron is reduced to the metallic state and becomes alloyed with the platinum, as the places where the slags have been in contact

* *Op. cit.*, p. 445. † *Op. cit.*, p. 309.

‡ See also Roscoe-Schorlemmer, *A Treatise on Chemistry*, New York, 1880, vol. ii., part ii., p. 399.

§ Barus, *Bulletin* No. 54, *U. S. Geol. Survey*, Washington, 1889, p. 187, and Graham-Otto, *Anorganische Chemie*, Brunswick, 1889, vol. iv., part ii., p. 1267.

with the platinum at this high temperature are rough and purplish-red to black; and this change is not superficial, but penetrates the platinum, which becomes very brittle.

The thermo-electric pyrometer of Le Chatelier, which is one of the standards for heat-measurement, was experimented with. The slag-mixture was moistened with a solution of dextrine, pressed around the junction in the form of a small ball, and heated slowly after it had been dried. The readings, however, were unsatisfactory, as it was difficult to fix the point at which the deflection of the galvanometer stopped; moreover, particles of the mixture dropped off from the junction; and, lastly, the smoky flame weakened the wires to such an extent that they broke off by their own weight.

The second method tried was the employment of Seger cones.* It proved satisfactory, and was used throughout the experiments. Seger cones furnish the most valuable means for controlling the temperature of a furnace in which mechanical mixtures are to be converted into chemical compounds by the use of heat. As a complete table of these cones has not yet appeared in the *Transactions*, the latest, as restandardized by Hecht with the Le Chatelier pyrometer, is here given in Table I.

Seger cones have the form of three-sided pyramids. Nos. 022 to 25 are 3 inches high, with a base $\frac{5}{8}$ inch wide,† Nos. 26–36 are $\frac{25}{32}$ inch high, with a base $\frac{3}{8}$ inch wide.‡ Each cone has its number stamped on the side, which usually remains uppermost when the cone bends over in melting. The order of numbering is peculiar, and is caused by the way in which the cones were brought out. When Seger found that gold-platinum alloys with over 15 per cent. of platinum showed segregation in melting, and wanted to substitute fusible mixtures used in glazing porcelain, he started with the most fusible one:

$$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\} 0.5\ Al_2O_3,\ 4SiO_2.$$

* *Thonindustrie-Zeitung*, 1885, 104, 121; 1886, 135, 145, 168, 229; 1887, 2, 40, 42, 52, 81, 83, 125, 185, 197; 1888, 61, 152, 162; 1889, 102; 1892, 155, 294; 1893, 1252, 1281, 1337, 1341; 1894, 89, 90, 206; 1895, 73, 88, 117, 803; 1896, 1, 275, 293; 1898, 670, 1045. *The Clay-Worker*, 1896, xxv., 261; 1897, xxviii., 111. *Trans.*, xxiv., 49, 54; xxv., 4, 8; xxviii., 435, 440. 18th *Ann. Report U. S. Geol. Survey*, 1897, part v., "Mineral Resources," p. 1125.

† Illustration, see *Trans.*, xxiv., p. 65.

‡ Illustration, see *Trans.*, xxv., p. 8.

TABLE I.—*Seger Cones.*

No. of Cone.	Composition.			Melting-Point. °F.	Melting-Point. °C.
022	0.5 Na_2O, 0.5 PbO	....	2.0 SiO_2, 1.0 B_2O_3	1,094	590
021	0.5 Na_2O, 0.5 PbO	0.10 Al_2O_3	2.2 SiO_2, 1.0 B_2O_3	1,148	620
020	0.5 Na_2O, 0.5 PbO	0.20 Al_2O_3	2.4 SiO_2, 1.0 B_2O_3	1,202	650
019	0.5 Na_2O, 0.5 PbO	0.30 Al_2O_3	2.6 SiO_2, 1.0 B_2O_3	1,256	680
018	0.5 Na_2O, 0.5 PbO	0.40 Al_2O_3	2.8 SiO_2, 1.0 B_2O_3	1,310	710
017	0.5 Na_2O, 0.5 PbO	0.50 Al_2O_3	3.0 SiO_2, 1.0 B_2O_3	1,364	740
016	0.5 Na_2O, 0.5 PbO	0.55 Al_2O_3	3.1 SiO_2, 1.0 B_2O_3	1,418	770
015	0.5 Na_2O, 0.5 PbO	0.60 Al_2O_3	3.2 SiO_2, 1.0 B_2O_3	1,472	800
014	0.5 Na_2O, 0.5 PbO	0.65 Al_2O_3	3.3 SiO_2, 1.0 B_2O_3	1,526	830
013	0.5 Na_2O, 0.5 PbO	0.70 Al_2O_3	3.4 SiO_2, 1.0 B_2O_3	1,580	860
012	0.5 Na_2O, 0.5 PbO	0.75 Al_2O_3	3.5 SiO_2, 1.0 B_2O_3	1,634	890
011	0.5 Na_2O, 0.5 PbO	0.80 Al_2O_3	3.6 SiO_2, 1.0 B_2O_3	1,688	920
010	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	3.50 SiO_2, 0.50 B_2O_3	1,742	950
09	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	3.55 SiO_2, 0.45 B_2O_3	1,778	970
08	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	3.60 SiO_2, 0.40 B_2O_3	1,814	990
07	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	3.65 SiO_2, 0.35 B_2O_3	1,850	1,010
06	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	3.70 SiO_2, 0.30 B_2O_3	1,886	1,030
05	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	3.75 SiO_2, 0.25 B_2O_3	1,922	1,050
04	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	3.80 SiO_2, 0.20 B_2O_3	1,958	1,070
03	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	3.85 SiO_2, 0.15 B_2O_3	1,994	1,090
02	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	3.90 SiO_2, 0.10 B_2O_3	2,030	1,110
01	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	3.95 SiO_2, 0.05 B_2O_3	2,066	1,130
1	0.3 K_2O, 0.7 CaO	0.20 Fe_2O_3, 0.30 Al_2O_3	4 SiO_2	2,102	1,150
2	0.3 K_2O, 0.7 CaO	0.10 Fe_2O_3, 0.40 Al_2O_3	4 SiO_2	2,138	1,170
3	0.3 K_2O, 0.7 CaO	0.05 Fe_2O_3, 0.45 Al_2O_3	4 SiO_2	2,174	1,190
4	0.3 K_2O, 0.7 CaO	0.5 Al_2O_3	4 SiO_2	2,210	1,210
5	0.3 K_2O, 0.7 CaO	0.5 Al_2O_3	5 SiO_2	2,246	1,230
6	0.3 K_2O, 0.7 CaO	0.6 Al_2O_3	6 SiO_2	2,282	1,250
7	0.3 K_2O, 0.7 CaO	0.7 Al_2O_3	7 SiO_2	2,318	1,270

TABLE I.—*Seger Cones.—Continued.*

No. of Cone.	Composition.			Melting-Point.	
				°F.	°C.
8	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	0.8 Al_2O_3	8 SiO_2	2,354	1,290
9	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	0.9 Al_2O_3	9 SiO_2	2,390	1,310
10	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	1.0 Al_2O_3	10 SiO_2	2,426	1,330
11	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	1.2 Al_2O_3	12 SiO_2	2,462	1,350
12	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	1.4 Al_2O_3	14 SiO_2	2,498	1,370
13	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	1.6 Al_2O_3	16 SiO_2	2,534	1,390
14	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	1.8 Al_2O_3	18 SiO_2	2,570	1,410
15	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	2.1 Al_2O_3	21 SiO_2	2,606	1,430
16	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	2.4 Al_2O_3	24 SiO_2	2,642	1,450
17	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	2.7 Al_2O_3	27 SiO_2	2,678	1,470
18	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	3.1 Al_2O_3	31 SiO_2	2,714	1,490
19	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	3.5 Al_2O_3	35 SiO_2	2,750	1,510
20	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	3.9 Al_2O_3	39 SiO_2	2,786	1,530
21	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	4.4 Al_2O_3	44 SiO_2	2,822	1,550
22	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	4.9 Al_2O_3	49 SiO_2	2,858	1,570
23	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	5.4 Al_2O_3	54 SiO_2	2,894	1,590
24	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	6.0 Al_2O_3	60 SiO_2	2,930	1,610
25	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	6.6 Al_2O_3	66 SiO_2	2,966	1,630
26	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	7.2 Al_2O_3	72 SiO_2	3,002	1,650
27	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$	20 Al_2O_3	200 SiO_2	3,038	1,670
28	....	1 Al_2O_3	10 SiO_2	3,074	1,690
29	....	1 Al_2O_3	8 SiO_2	3,110	1,710
30	....	1 Al_2O_3	6 SiO_2	3,146	1,730
31	....	1 Al_2O_3	5 SiO_2	3,182	1,750
32	....	1 Al_2O_3	4 SiO_2	3,218	1,770
33	....	1 Al_2O_3	3 SiO_2	3,254	1,790
34	....	1 Al_2O_3	2.5 SiO_2	3,290	1,810
35	....	1 Al_2O_3	2 SiO_2	3,326	1,830
36	....	1 Al_2O_3	1.5 SiO_2	3,362	1,850

NOTE.—In 1898, Hecht (*Thonind.-Zeit.*, 1898, p. 670), finding that the difference between Nos. 35 and 36 was rather large, interpolated an additional size, and also began to extend the series beyond No. 36.

He increased its fusibility by a partial substitution of ferric oxide for alumina, and obtained a mixture

$$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\} \quad \left\{\begin{matrix} 0.3\ Al_2O_3 \\ 0.2\ Fe_2O_3 \end{matrix}\right\} 4SiO_2$$

which melted at the same temperature as the alloy Au 90 : Pt 10, or at 1150° C. This formed No. 1 of his series. He then diminished the fusibility of his mixture, first by increasing the ratio of $Al_2O_3 : Fe_2O_3$, and then by dropping the Fe_2O_3 altogether. After this he increased the ratio of $SiO_2 : Al_2O_3$ until mixture No. 27 was reached, which melted at about 1670° C. With mixtures Nos. 28 to 36, melting at temperatures ranging from 1690 to 1850° C., the bases K_2O and CaO were discarded, and the ratio $Al_2O_3 : SiO_2$ was slowly increased. These mixtures proved so satisfactory that Cramer and Hecht prepared others for lower temperatures, ranging from 1150° C. to the melting-point of silver, 950° C., by replacing part of the SiO_2 with B_2O_3 and numbered them 010 to 01; finally, for mixtures below the melting-point of silver down to 590° C., Hecht replaced the CaO by PbO and the K_2O by Na_2O; he lastly dropped the Fe_2O_3 and decreased the Al_2O_3 and numbered these cones 022 to 011.* When several cones are placed in a furnace, the one with the lower number will always melt down before that with the higher number; and the temperature of a furnace corresponds to the cone, the tip of which, after bending over, will touch the base. The cones are, however, no true pyrometers; since the change of a mixture into a chemical compound by heating is not a function of temperature alone, but depends also upon the manner of firing, the time given, and the form of the furnace. This has been shown in a very interesting manner by Hecht† in firing different batches of porcelain at the Royal Prussian porcelain-factory, and controlling the operations by means of Seger cones and the Le Chatelier pyrometer. The temperatures given in the table correspond pretty closely to the control-measurements with the Le Chatelier pyrometer, as long as the heating is carried on slowly.

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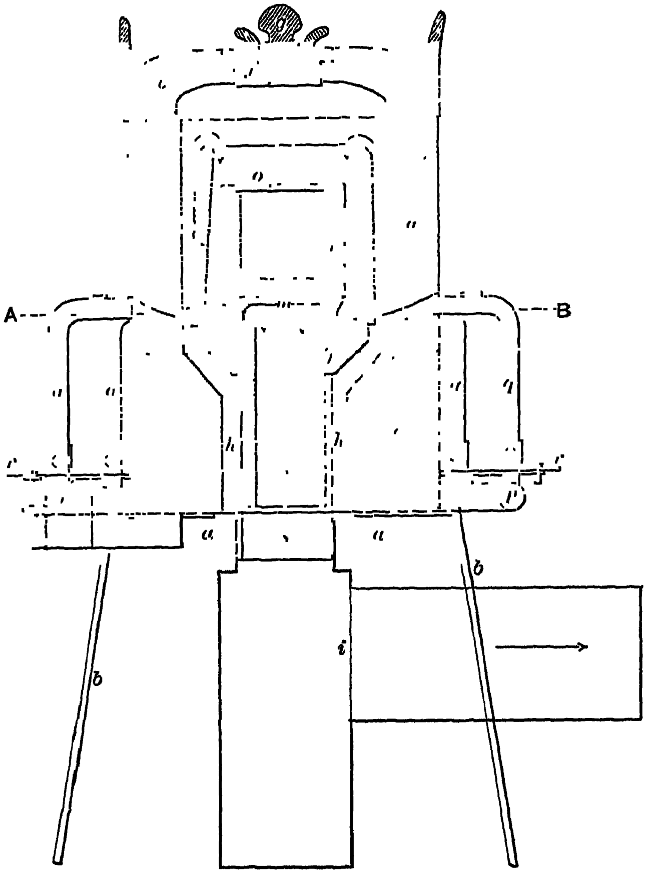
* All these cones are imported by Messrs. Eimer & Amend, Third Avenue, New York City, at $3.00 a 100 ; Nos. 010 to 20 are furnished at $1.00 a hundred by Prof. Edward Orton, Department of Ceramics and Clay-Working, Ohio State University, Columbus, Ohio.

† *Thonindustrie-Zeitung*, 1895, p. 803.

The advantage of using Seger cones in the experiments to be described lies in the fact that the cone, a mechanical mixture, is exposed to accurately the same influences as the slag-mixture to be tested; and if this is made up into cones of the same size and form as the Seger, the test leaves little to be desired. The

FIG. 1.



SEGER GAS FURNACE.
VERTICAL SECTION ON C-D FIG. 2.
Scale, ½ Natural Size.

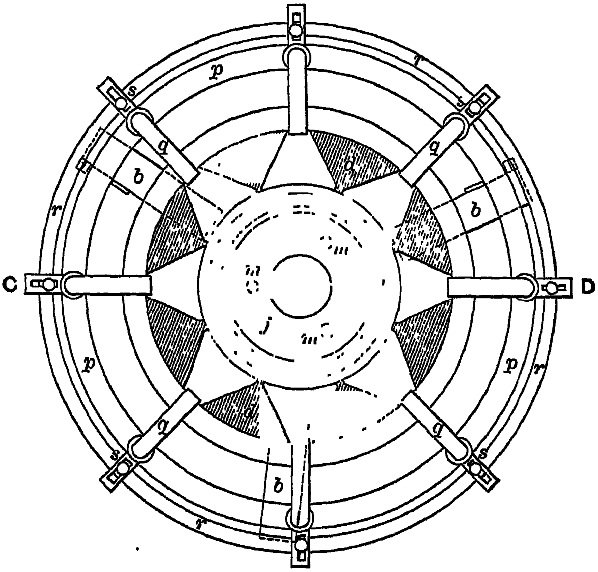
size of the small Seger cone, $\frac{25}{32}$ by $\frac{5}{8}$ inch, was chosen for the experiments; and Seger mixture and slag-mixture were moulded accordingly.

IV. THE FURNACE.

The furnace used in the experiments was that constructed by Seger for laboratory-work in testing low-grade clays, porce-

lains, glazes, etc. Figs. 1 and 2 show vertical and horizontal sections through the furnace. The outer wall, resting on an annular plate *a*, supported by the tripod *b*, consists of two wrought-iron cylindrical jackets, *c* and *d*, lined with refractory clay and placed one on top of the other, and a fire-brick cover, *e*, with an opening closed by a brick, *f*, and a peep-hole closed by the stopper *g*. The plate *a* supports by means of lugs the heavy wrought-iron pipe *h*; to the lower end of which is attached a stove-pipe carrying off the products of combustion into a chim-

FIG. 2.

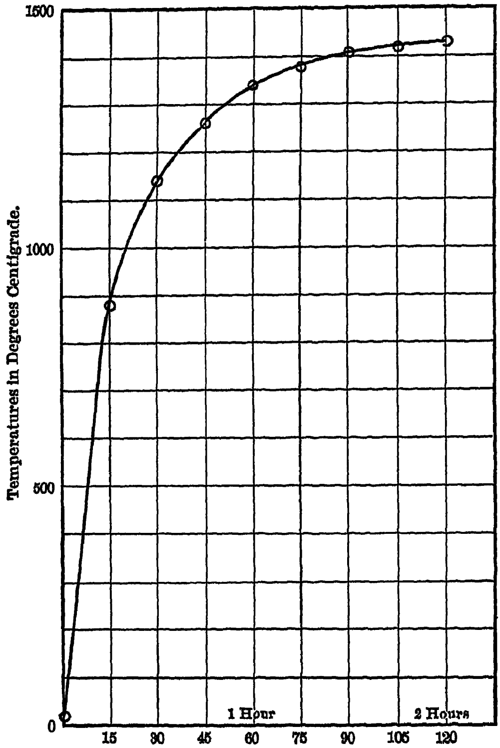


SEGER GAS FURNACE.
HORIZONTAL SECTION ON A-B FIG. 1.
Scale, ⅛ Natural Size.

ney, which must have a strong draught. Into the inside of the upper part fits closely a support of refractory material, *j*, which carries the annular fire-bridge *k* and a clay-plate with tripod *m* bearing the crucible *n*, with its cover *o*. The furnace is heated with illuminating-gas passing from the circular main pipe *p* into eight Bunsen burners *q*. The admission of air to all these is regulated by means of the flat ring *r* and sliding pins *s*. The flames from the burners ascend between the furnace-wall and the fire-bridge; are deflected by the roof, and descend between the fire-bridge and the crucible; pass under-

neath the crucible-support, and then downward to the pipe which draws off the products of combustion. The furnace can be started quickly or slowly; an oxidizing or reducing character can be given to the flame; the crucible is uniformly heated, and whatever goes on in it can be observed from without. It is easy to obtain 1400° C. in the furnace; and, by running three hours, it is possible to reach 1600° C. The amount

FIG. 3.



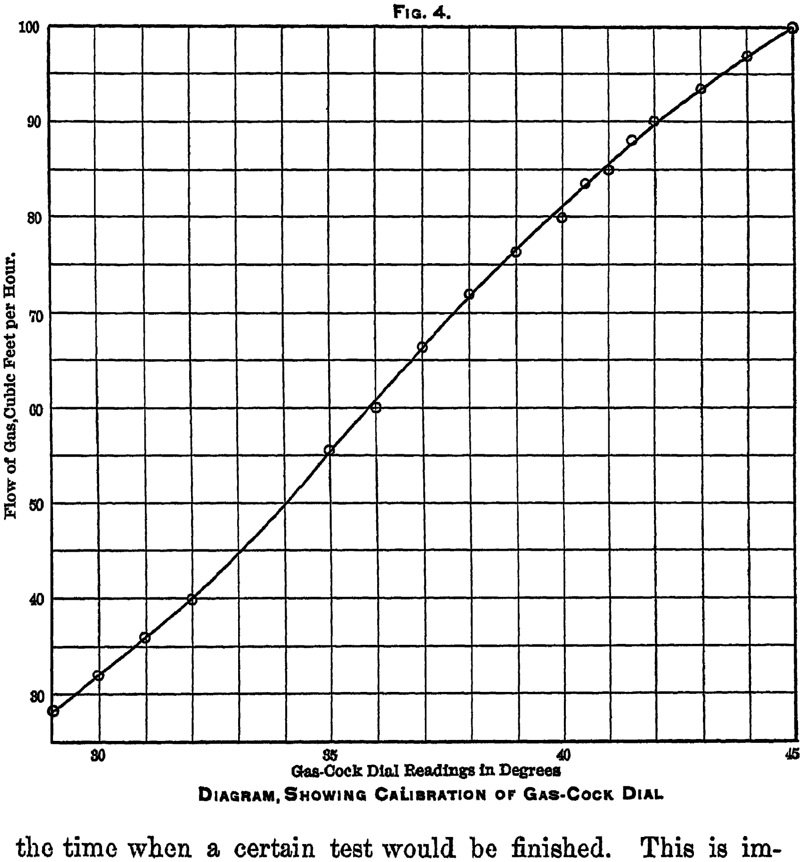
DIAGRAM, SHOWING THE RATE OF HEATING-UP FURNACE, BURNING 130 CUB. FT. OF GAS PER HOUR.

of gas consumed is small, ranging in these experiments from 30 to 150 cubic feet per hour. Fig. 3 shows the increase of temperature in the crucible, as measured with the Le Chatelier pyrometer, when 130 cubic feet of gas were consumed per hour. The abscissa gives the time in minutes after lighting the furnace; the ordinate, the progressive rise of temperature in degrees Centigrade. To these figures the room-temperature, say 20° C., should be added, to make the actual temperature.

In order to regulate the admission of gas carefully, a dial-cock was used. The gas from the main passed through a meter, and then through the dial-cock into the furnace.

Fig. 4 is a diagram in which the abscissa shows the angular reading on the dial, and the ordinate the corresponding quantity of gas that passed through the cock per hour. After having become familiar with the furnace, we found it possible, by turning on a certain flow of gas, to approximate beforehand

FIG. 4.



DIAGRAM, SHOWING CALIBRATION OF GAS-COCK DIAL

the time when a certain test would be finished. This is important; because, when more than 75 cubic feet of gas are burnt per hour, it is not possible to see down into the crucible. When an observation is to be made, the gas is turned down for a moment to the dial-point corresponding to 75 cubic feet per hour. In order to see clearly, smoked glasses are necessary; tints Nos. 2, 4 and 6 proved satisfactory, the darker glass being used for the higher temperature.

In carrying out the large number of experiments recorded below, only two fire-bridges and two crucibles, but a considerable number of covers, were required. A cover will last only about ten heats. An ordinary 5-inch Battersea roasting-dish, with a hole bored in the bottom, makes a good cover.

The lining of the furnace cracked immediately on starting, probably on account of heating up too quickly; but, being held by an iron jacket, it is as good to-day as it was at first, no attempt having been made to fill the crack.

V. Method of Operation.

In preparing the cones of a slag-mixture, the ingredients were weighed out and mixed dry in a porcelain dish. They were then moistened on a glass plate, from a wash-bottle, with a 10-per-cent. dextrine solution, worked with a spatula to a stiff paste and molded into the form of a small-sized ($\frac{3}{8}$ inch base, $\frac{25}{32}$ inch height) Seger cone.* As the low-grade Seger cones to be used for the experiments are sold only in large sizes ($\frac{3}{4}$ inch base, $2\frac{3}{8}$ inch height), the loose mixture was procured and molded into the small size as required.

As support for the cones, platinum foil bent into the form of a tray, with one side open, was used. This tray was $1\frac{1}{2}$ inches long, $1\frac{1}{4}$ inches wide and $\frac{1}{4}$ inch deep. To protect it, a false bottom of scrap-platinum was placed in the tray, and on this were set one or two slag-cones with several Seger cones. When a fusion was finished, the tray, with the cones adhering to the false bottom, was taken out. The Seger cones usually came off quite easily, as did occasionally also all of the slag-cones; but generally some adhering parts could only be removed by treatment with strong hydrochloric acid; and frequently heating in acid potassium sulphate, fused in a clay crucible, was necessary. By the use of the tray with a false bottom, the outlay for platinum consumed in the experiments was reduced to a low figure.

As it was essential to have a reducing atmosphere, a reducing agent that would be readily oxidized was required in the crucible. Oil-carbon was chosen. It was cut into segments and fitted into the crucible so as to make a lining 2 or more

* For description of tools, see *Trans.*, xxv., pp. 10, 11.

inches high, and thus completely to surround the test. Oil-carbon has practically no ash; in order to prevent the little that it contains from adhering to the bottom of the crucible, this was covered with a thin layer of pure alumina. As a rule, oil-carbon contains some volatile matter, which gives a thick smoky flame when the furnace is being started up. It was noticed that this smoky flame reduced the melting-points, the difference occasionally reaching 80° C. Since it was impossible to grade the flame, all experiments were made when the crucible had been freed from flame, thus insuring uniform conditions.

In starting the furnace after the crucible had been charged, the openings for admitting air to the Bunsen burners are closed by moving the ring *r*, Figs. 1 and 2; the gas-cock is slightly opened, and the gas is ignited. Now the cover is put in place, and a small amount of air is admitted to the burners, until the flame becomes blue. The admission of gas and air is then increased, much more slowly, however, than is shown in Fig. 3, which represents a somewhat rapid heating-up. It takes from one to three hours to make a test; the time, of course, varying inversely with the fusibility of the mixture in the crucible.

While the experiment is going on the cones must be very carefully watched. As soon as a slag-cone is seen to be partly melted, the gas is shut off; the brick in the cover is removed; the furnace is allowed to cool below a dark-red; the cover is taken off; then the lid of the crucible is removed; the platinum tray is taken out with cupel-tongs; and another tray, bearing its samples, is put in position and a new test is started. It is absolutely necessary to stop heating as soon as a slag-cone is seen to be partially melted; for, if the heating be continued 15 to 30 seconds longer, the cone will have flattened out completely, and will often have become so fluid as to run like water. When a slag-cone has thus flattened out, it is hardly possible to compare it with a Seger cone, which always bends over slowly; but at the right moment, just before flattening out, a comparison is easy and accurate. The Seger cone most nearly resembling the slag-cone in appearance at that moment is considered to have the same melting-point.

The weakness of the method followed in these experiments lies in the fact that the end-point chosen for the slag-cone is

not fixed, but optional with the experimenter: thus all results given may be too high or too low by 50° C. But, an end-point having been settled upon and the experiments being all carried out by the same person, the results will show very little variation, probably not more than 5° C. Some of the irregularities in the curves, which it would be unreasonable to attribute to the peculiar behavior of certain silicates, may be explained by a greater or smaller amount of iron present as magnetic oxide instead of ferrous oxide, and thus decreasing the fusibility of the mixture. The fact that a slag-mixture will suddenly become fluid when the ingredients have been heated to the point where they unite to form as slag, strongly indicates the generally accepted conclusion, first suggested (it is believed) by Plattner,* that the formation-temperature of a slag is higher than the melting-point of the slag once formed.

VI. Ground Covered by Experiments.

The sub-, singulo-, sesqui-, and bi-silicates, being the ferrous slags commonly made in blast-furnace work, constituted the main subject of investigation. The data necessary for making up the mixtures were taken from the slag-table calculated several years ago by Prof. R. H. Richards for use in class-work. (See Table II.) Although all the figures in this table were not used, it is printed in full, because it is new in technical literature, and gives facts of much value for all sorts of slag-calculations. It comprises the ferrous slags ranging from the highly basic sub-silicate $5RO, SiO_2$ to the highly acid quadri-silicate $RO, 2SiO_2$. Each silicate-series starts with the ferrous silicate, free from calcium oxide, and replaces the ferrous oxide by 4, 8, 12, etc., per cent. of calcium oxide, until a practical limit of the percentage of calcium oxide has been reached.

In the experiments here described.

1. The formation-temperatures were determined for the sub-silicates $4RO, SiO_2$ and $3RO, SiO_2$; the singulo-silicate, $2RO, SiO_2$; the three-to-four silicate, $3RO, 2SiO_2$; the sesqui-silicate, $4RO, 3SiO_2$; and the bi-silicate RO, SiO_2, as given in Table II.

2. The formation-temperatures were determined for a cross-series of slags, starting from the sub-silicate, $4RO, SiO_2$, and

* *Op. cit.*, p. 333.

TABLE II.—*Ferrous and Calcic Silicates Showing Gradations from Highly Basic to Highly Acid Compounds and from all Ferrous to nearly all Calcic Silicates.*

Formulæ of Silicates.	O. in Bases to O. in Acids.		Per Cent.													
5RO SiO_2	5 : 2	FeO	85.70	81.55	77.38	73.23	69.05	64.90	60.74	56.57	52.41	48 25	44.10	39.92	35 67	31.60
		CaO	0.	4.	8.	12.	16.	20.	24	28.	32.	36.	40.	44	48	52.
		SiO_2	14.30	14.45	14.62	14.77	14.95	15 10	15 26	15.43	15.60	15.75	15 90	16 08	16 33	16 40
4RO SiO_2	4 : 2	FeO	82 80	78 60	74.40	70.23	66 01	61.81	57.61	53.41	49 22	45.02	40 81	36 61	32.41	28.20
		CaO	0.	4.	8.	12.	16.	20	24.	28.	32.	36.	40.	44.	48.	52.
		SiO_2	17.20	17.40	17.59	17.77	17.99	18 19	18 39	18.59	18.78	18 98	19.19	19.39	19 59	19.80
3RO SiO_2	3 : 2	FeO	78.30	74.05	69.80	65 51	61.30	57.05	52.80	48.55	44 30	40.06	35.80	31.55	27.52	28 05
		CaO	0.	4	8.	12.	16.	20	24.	28.	32.	36.	40.	44.	48	52.
		SiO_2	21.70	21.95	22 20	22.49	22 70	22.95	23.20	23.45	23.70	23 94	24.20	24 45	24 48	24.95
5RO $2SiO_2$	5/2 : 2	FeO	75.00	70 71	66.48	62.15	57.86	53 57	49,28	45.	40.71	36.43	32.15	27 86	23.50	19 28
		CaO	0.	4.	8.	12.	16.	20.	24.	28.	32.	36	40	44.	48.	52.
		SiO_2	25 00	25.28	25 57	25.85	26.14	26.43	26 72	27.	27.29	27.57	27 86	28.14	28 43	28.72
2RO SiO_2	2 : 2	FeO	70 80	66.25	61.91	57.58	53.24	48.90	44.60	40.80	35.90	31.70	27.30	22.90	18.56	14.21
		CaO	0.	4.	8.	12.	16.	20.	24.	28.	32.	36.	40	44.	48.	52.
		SiO_2	29.20	29.75	30.09	30 42	30.76	31 07	31.40	31.70	32.10	32 30	32.70	33 10	33.44	33 79
5RO $3SiO_2$	5/3 : 2	FeO	66.66	62.26	57.92	53.58	49 24	44.93	40.56	36,22	31.88	27.54	23 20	18 86	14.52	10.10
		CaO	0.	4.	8.	12.	16.	20.	24.	28.	32.	36.	40.	44.	48.	52
		SiO_2	33.33	33.74	34.08	34.42	34.76	35.07	35 44	35.78	36.12	36 46	36.80	37 14	37 48	37.90
3RO $2SiO_2$	3/2 : 2	FeO	64.30	60.00	55.60	51 20	46 70	42.25	37.84	33.44	29 04	21.63	20 22	15.80	11 40	6.98
		CaO	0.	4.	8.	12.	16.	20.	24.	28.	32.	36.	40.	44.	48.	52
		SiO_2	35 70	36 05	36.40	36.80	37.30	37.75	38.16	38.56	38.95	39.37	39 78	40 20	40 60	41 02
4RO $3SiO_2$	4/3 : 2	FeO	61.54	57.10	52.66	48.22	43.78	39.34	34.89	30.46	26.01	21.58	17 13	12 69	8.26	8.81
		CaO	0.	4	8.	12.	16.	20.	24.	28.	32.	36.	40.	44.	48.	52.
		SiO_2	38.46	38.90	39 34	39.78	40 22	40 66	41.11	41.54	41 99	42.42	42 87	43 31	43.75	41.19
5RO $4SiO_2$	5/4 : 2	FeO	60.00	55.54	51 08	46 63	42.17	37.72	33 26	28.80	24 35	19.89	15 43	10.97	6 52	2.06
		CaO	0.	4.	8.	12	16.	20.	24.	28.	32.	36.	40.	44	48.	52.
		SiO_2	40.00	40 46	40.92	41.37	41.83	42 28	42.74	43 20	43.61	41.11	44 57	45.03	45 48	45 91
RO SiO_2	1 : 2	FeO	54 55	50.00	45.47	40 96	36.44	31.98	27 43	22.81	18.40	13 89	9 37	1.86	0.35	0 00
		CaO	0.	4.	8.	12.	16.	20.	24.	28.	32.	36.	40	44	48.	48 27
		SiO_2	45.45	46 00	46 53	47 04	47.56	48 02	48 57	49.19	49.60	50 11	50 63	51.14	51.65	51.73
4RO $5SiO_2$	4/5 : 2	FeO	48.98	44.40	39.91	35.23	30.65	26.07	21.49	16.90	12 41	7.74	3.16	0 00		
		CaO	0.	4.	8.	12.	16.	20.	24.	28.	32.	36.	40.	42 75		
		SiO_2	51.02	51.60	52 09	52 77	53 35	53.98	54.51	55 10	55 59	56 26	56.84	57.25		
3RO $4SiO_2$	3/4 : 2	FeO	47 37	42.76	38.19	33.58	28 98	24.37	19.77	15 16	10.55	5 95	1.35	0.00		
		CaO	0.	4.	8.	12.	16	20.	24.	28	32	36	40	41.18		
		SiO_2	52 63	53.24	53.81	54.42	55.02	55 63	56.23	56 84	57 45	58.05	58 65	58.82		
2RO $3SiO_2$	2/3 : 2	FeO	44.44	39.77	35 14	30 51	25.88	21 24	16 60	11.96	7.32	2.68	0.00			
		CaO	0.	4.	8.	12.	16.	20	24.	28.	32.	36.	38.36			
		SiO_2	55 55	56.23	56.86	57.49	58.12	58 76	59.40	60 04	60.58	61.32	61.64			
3RO $5SiO_2$	3/5 : 2	FeO	41.86	37.05	32 41	27 76	23.13	18.47	14.88	9.18	4.53	0 00				
		CaO	0.	4.	8.	12.	16.	20.	24.	28	32	35 90				
		SiO_2	58.14	58.95	59.59	60 24	60 87	61 58	61 17	62.82	63 47	64.10				
RO $2SiO_2$	1/2 : 2	FeO	37 50	32 79	28.08	23.37	18.66	13 95	10 24	4.53	0 00					
		CaO	0.	4.	8	12.	16.	20.	24.	28	31 82					
		SiO_2	62.50	63.21	63 92	64.63	65 34	66 05	65.76	67.37	68.18					

extending to the tri-silicate, $2RO, 3SiO_2$; the percentage of ferrous oxide being kept at twice that of calcium oxide, with the purpose of studying the effects of a steadily increasing percentage of silica.

3. A singulo-silicate, in which the percentages of silica, ferrous oxide and calcium oxide were most evenly divided (SiO_2, 32.1; FeO, 35.9; CaO, 32.0), was chosen, and the effects of replacing the constituents with manganous oxide, magnesia, baryta, zinc oxide and alumina, were studied.

VII. Record of Results.

In recording the results obtained with the silicate-series, a table is given (see Tables III. to VIII.) for each series of experiments; and the whole is followed by two diagrams (Figs. 5 and 6). The tables show the composition of the mixtures in percentages; the percentages of the bases, ferrous and calcium oxide, referred to the sum of their equivalents;* the numbers of the Seger cones which fused simultaneously with the mixtures; and the corresponding temperature in degrees C. The two diagrams, Figs. 5 and 6, give assembled graphic representations of the tabulated results. The object of calculating and plotting the percentage-equivalents, in addition to the percentages by weight, was to show the relative fluxing-effects by chemical replacement of ferrous and calcium oxide. Thus, in taking as abscissæ the percentage-equivalents of FeO and CaO, it will be seen that for the points X, in the curves (III*a*–VIII*a*) where the abscissa is, *e. g.*, 20 per cent. CaO, or 80 per cent. FeO, the SiO_2 is combined with CaO and FeO in the proportion of 1 : 4.

The cross-series is represented in Table IX., which gives the composition by weight, the silicate-degree, the numbers of the

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* $\frac{\text{Per cent. CaO}}{\text{Mol. w't. CaO}}+\frac{\text{Per cent. FeO}}{\text{Mol. w't. FeO}}=$Total, to be reduced to 100.

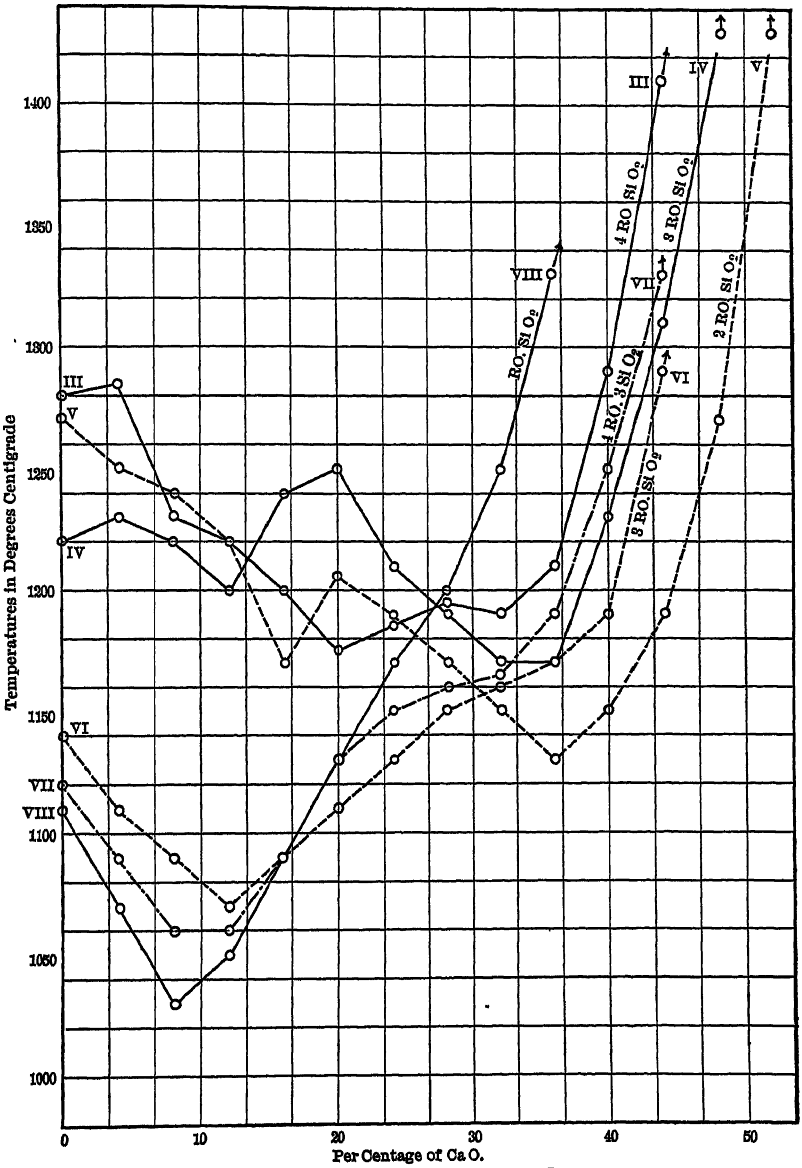
To give an example: In Table V. the second slag has the composition SiO_2, 29.75; FeO, 66.25; CaO, 4 per cent. Putting the values for CaO and FeO into the above formula, we have

$$\frac{4}{56}+\frac{66.25}{72}=0.071+0.921=0.992.$$

To reduce these figures to percentages, they must be multiplied by 100.8, since $0.992 \times 100.8=100$. Thus, $0.071 \times 100.8=7.1568$ (given roundly in the table as 7.2); and $0.921 \times 100.8=92.83$ (given roundly in the table as 92.80).

Seger cones, and the corresponding temperatures, and is followed by a diagram (Fig. 7).

FIG. 5.

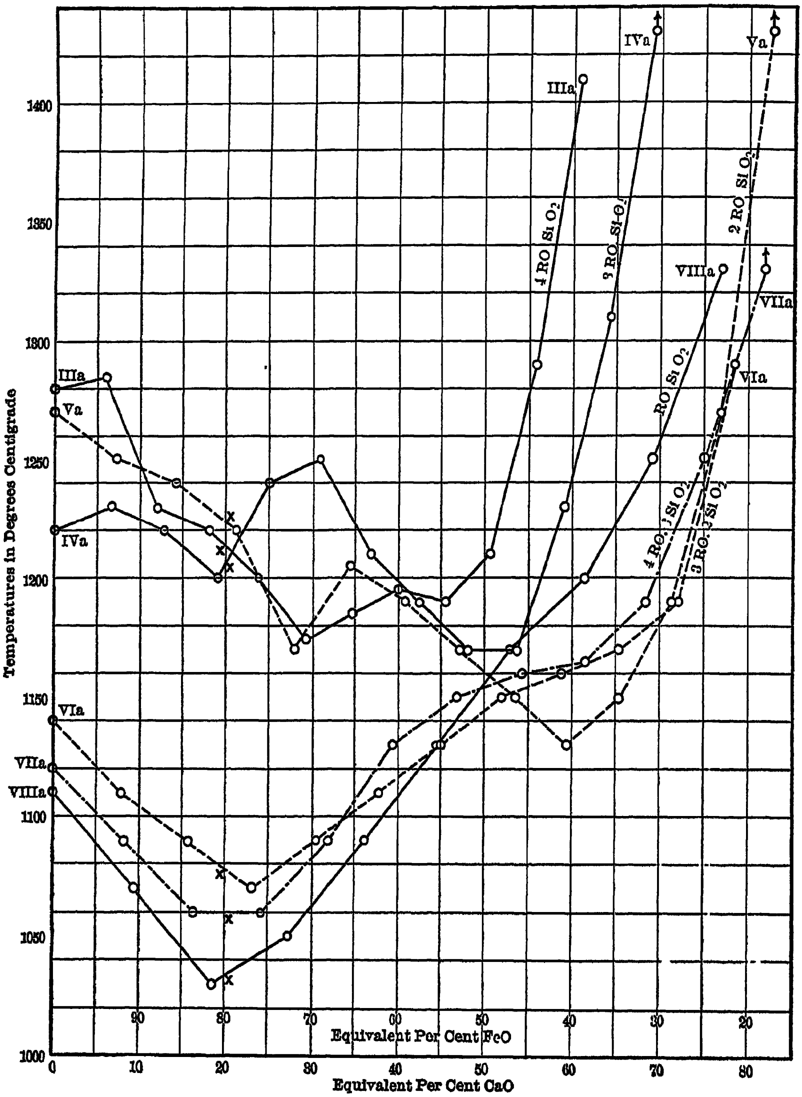


THE FORMATION OF FERRO-CALCIC SILICATES

Tables X. to XXI., inclusive, represent the replacement of the regular slag-constituents in the lead slag. and show how ferrous oxide has been replaced successively by $\frac{1}{8}$, $\frac{2}{8}$, $\frac{3}{8}$ . . . . $\frac{8}{8}$ of its

equivalent of manganous oxide; calcium oxide by magnesium, barium and zinc oxide; and silica, and ferrous and calcium oxide by aluminum oxide. Each table gives the numbers

FIG. 6.

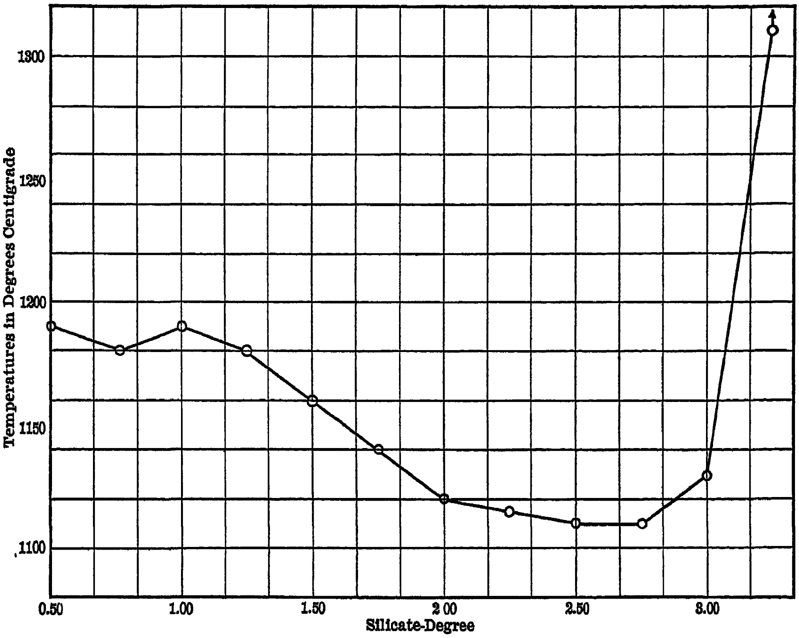


THE FORMATION OF FERRO-CALCIC SILICATES

of the Seger cones corresponding to the fusions with the degrees C. These tables are followed by three diagrams (Figs. 8 to 10 inclusive), which graphically represent the same results.

Some of the general physical properties of the slags have already been given. Figs. 5 and 6 show the temperatures at which the different slags were formed. In both, the ordinate represents the degrees C.; the abscissa in Fig. 5 shows the percentage of calcium oxide in the slags by weight, while in Fig. 6 the equivalent percentages of ferrous and calcium oxide, based on the sum of the two, are given. As the curves in Fig.

FIG. 7.



CROSS-SERIES, SHOWING EFFECT OF INCREASE OF SILICA UPON FORMATION-TEMPERATURE.

6 show the same general character as those of Fig. 5, the discussion of temperatures in this paper is based on Fig. 5.

The Sub-Silicate, $4RO, SiO_2$. (Table III. and Fig. 5, Curve III.)

The formation-temperature of the pure ferrous silicate (SiO_2, 17.20; FeO, 82.80) is 1280° C. A replacement of FeO by 4 per cent. CaO slightly raises this temperature; but with a further increase of CaO, it falls until the minimum of 1175° C. is reached with 20 per cent. CaO. A further increase, up to 36 per cent. CaO, slowly raises the formation-temperature to 1210° C., when with still more CaO the curve is seen to ascend rapidly.

TABLE III.—*Formation of the Sub-Silicate, $4RO, SiO_2$.* (See Figs. 5 and 6, Curves III. and III*a*.)

Chemical Composition of Slag.			Equivalent Per Cent. on Si (FeO, CaO).		Melting-Point.	
SiO_2. Per cent.	FeO. Per cent.	CaO. Per cent.	FeO. Per cent.	CaO. Per cent	Seger Cone. No.	Degrees, C.
17.20	82.80	0	100.00	0.00	7½	1,280
17.40	78.60	4	93.86	6.14	7¾	1,285
17.59	74.40	8	87.86	12.14	5	1,230
17.77	70.23	12	81.99	18.01	4½	1,220
17.99	66 01	16	76.25	23.75	3½	1,200
18.19	61.81	20	70.63	29.37	2¼	1,175
18.39	57.61	24	65.14	34.86	2¾	1,185
18.59	53.41	28	59.74	40.26	3¼	1,195
18.78	49.22	32	54.49	45.51	3	1,190
18.98	45.02	36	49.31	50 69	4	1,210
19.19	40.81	40	44.25	55.75	8	1,290
19.39	36.61	44	39.29	60.71	14	1,410
19.59	32.41	48	34.46	65.54	15 +	1,430 +
19.80	28.20	52	29.69	70.31	15 +	1,430 +

The Sub-Silicate, $3RO, SiO_2$. (Table IV. and Fig. 5, Curve IV.)

The pure ferrous silicate (SiO_2, 21.70; FeO, 78.30), although more siliceous than the preceding one, has a lower formation-temperature, viz., 1220° C. A replacement of FeO by 4 per cent. of CaO slightly raises the temperature, while 8 per cent. of CaO brings it down again to 1220° C., and the temperature sinks until 12 per cent. CaO is reached, and then, with more CaO, suddenly rises from the first minimum of 1200° C. to the first maximum of 1250° C., with 20 per cent. of CaO. With a further increase of CaO, it falls to the second and lowest minimum of 1170° C., with 32 to 36 per cent. of CaO, and then rises quickly with every small further addition of CaO.

In both the sub-silicates, an addition of 4 per cent. CaO to the pure ferrous silicate causes a rise of the formation-temperature, which, upon further addition, soon falls below the starting-point. The curves are only 20° C. apart at 12 per cent. CaO; they then diverge, but come together again so as to coincide (1190 and 1195° C.) at 28 per cent. CaO; and they reach their lowest points (1190 and 1170° C.) at 32 per cent. CaO.

TABLE IV.—*Formation of the Sub-Silicate*, $3RO, SiO_2$. (See Figs. 5 and 6, Curves IV. and IV*a*.)

CHEMICAL COMPOSITION OF SLAG.			EQUIVALENT PER CENT. ON Si (FeO, CaO).		MELTING-POINT.	
SiO_2. Per cent.	FeO. Per cent.	CaO. Per cent.	FeO. Per cent.	CaO. Per cent.	Seger Cone. No.	Degrees, C.
21.70	78.30	0	100 00	0.00	4½	1,220
21.95	74.05	4	93.51	6.49	5	1,230
22.20	69.08	8	87.17	12.83	4½	1,220
22.49	65.51	12	81.96	18.04	3½	1,200
22.70	61.30	16	74.91	25.09	5½	1,240
22.95	57.05	20	68.97	31.03	6	1,250
23.20	52.80	24	63.15	36.85	4	1,210
23.45	48.55	28	57.45	42.55	3	1,190
23.70	44.30	32	51.91	48.09	2	1,170
23.94	40.06	36	46.46	53.54	2	1,170
24.20	35.80	40	41.08	58.92	5	1,230
24.45	31.55	44	35.85	64.15	9	1,310
24.48	27.52	48	30.69	69.31	15 +	1,430 +
24.95	23.05	52	25.69	74.31	15 +	1,430 +

The Singulo-Silicate, $2RO, SiO_2$. (Table V. and Fig. 5, Curve V.)

The great regularity of this curve is perhaps the explanation of the fact that this slag has become such a favorite in blast-furnace work. The pure ferrous silicate (SiO_2, 29.20; FeO, 70.80) is formed at 1270° C., and this temperature is uniformly lowered with the replacement of FeO by CaO (excepting a sudden depression between 12 and 20 per cent. CaO), until the minimum of 1130° C. is reached with 36 per cent. CaO, after which it is raised by further additions of CaO, at first slowly, but then very quickly. The exceptional depression at 16 per cent. CaO was determined by repeated experiments, since it seemed at first that 12 and 20 per cent. CaO ought to have been joined by straight line. The slag resembles closely one of the standard typical lead-slags, namely, the one invented by Mr. A. Eilers*,

$$6FeO, 3SiO_2 + 2CaO, SiO_2$$

SiO_2, 30.61; FeO, 55.10; CaO., 14.29 per cent.,

which is known to have a very low formation-temperature and is used with zincose ores requiring low temperatures and quick smelting.

* See Hofman, *Lead*, 5th edition, p. 276.

The curve, after the depression, shows how it is that singulo-silicates high in CaO can be advantageously made in a blast-furnace, where a comparatively low temperature is to be maintained.

FIG. 8.

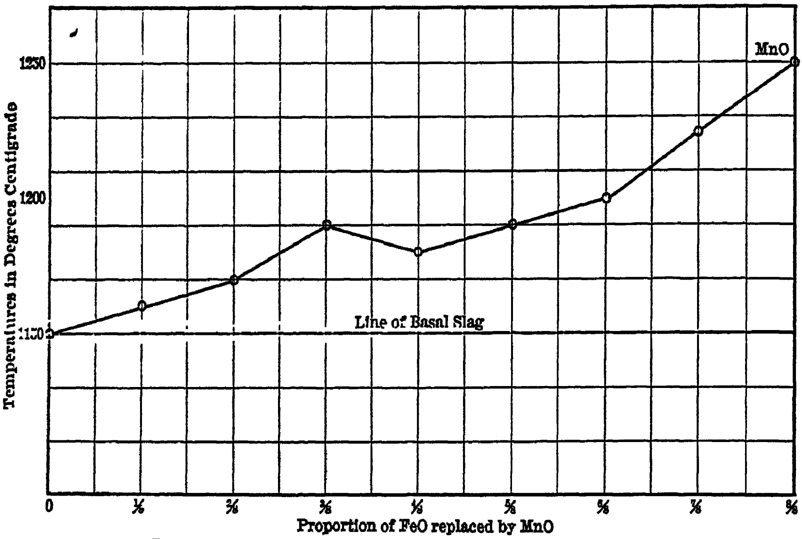


DIAGRAM SHOWING EFFECT OF REPLACEMENT OF FE O BY MN O.

TABLE V.—*Formation of the Singulo-Silicate*. $2RO, SiO_2$. (See Figs. 5 and 6, Curves V. and V*a*.)

CHEMICAL COMPOSITION OF SLAG.			EQUIVALENT PER CENT. ON Si (FeO, CaO).		MELTING-POINT.	
SiO_2. Per cent.	FeO. Per cent.	CaO. Per cent.	FeO. Per cent.	CaO. Per cent.	Seger Cone. No.	Degrees, C.
29.20	70.80	0	100.00	0.00	7	1,270
29.75	66.25	4	92.80	7.20	6	1,250
30.09	61.91	8	85.75	14.25	5½	1,240
30.42	57.58	12	78.87	21.13	4½	1,220
30.76	53.24	16	72.12	27.88	2	1,170
31.07	48.93	20	65.55	34.45	3¾	1,205
31.40	44.60	24	59.12	40.88	3	1,190
31.70	40.30	28	52.80	47.20	2	1,170
32.10	35.90	32	46.60	53.40	1	1,150
32.30	31.70	36	40.66	59.34	01	1,130
32.70	27.30	40	34.67	65.33	1	1,150
33.10	22.90	44	28.81	71.19	3	1,190
33.44	18.56	48	23.12	76.88	7	1,270
33.79	14.21	52	17.55	82.45	15 +	1,430 +

The Three-to-Four Silicate, $3RO, 2SiO_2$. (Table VI. and Fig. 5, Curve VI.)

The pure ferrous silicate (SiO_2, 35.70; FeO, 64.30), although running high in SiO_2, is formed at the low temperature of 1140° C. An addition of CaO, up to 12 per cent., decreases the temperature to the minimum of 1070° C. A further increase in CaO raises the formation-temperature at first somewhat slowly, but later rapidly, as was the case with the preceding slags.

TABLE VI.—*Formation of the Three-to-Four Silicate*, $3RO, 2SiO_2$. (See Figs. 5 and 6, Curves VI. and VI*a*.)

Chemical Composition of Slag.			Equivalent Per Cent. on Si (FeO, CaO).		Melting-Point.	
SiO_2. Per cent.	FeO. Per cent.	CaO. Per cent.	FeO. Per cent.	CaO. Per cent.	Seger Cone. No.	Degrees, C.
35.70	64.30	0	100.00	0.00	01½	1,140
36.00	60.00	4	92.10	7.90	02	1,110
36.40	55.60	8	84.39	15.61	03	1,090
36.80	51.20	12	76.85	23.15	04	1,070
37.30	46.70	16	69.42	30.58	03	1,090
37.75	42.25	20	62.17	37.83	02	1,110
38.16	37.84	24	55.07	44.93	01	1,130
38.56	33.44	28	48.17	51.83	1	1,150
38.95	29.04	32	41.40	58.60	1½	1,160
39.37	24.63	36	34.75	65.25	2	1,170
39.78	20.22	40	28.22	71.78	3	1,190
40.20	15.80	44	21.83	78.16	8	1,290
40.60	11.40	48	15.63	84.37	15 +	1,430
41.02	6.98	52	9.46	90.54	......	......

The Sesqui-Silicate, $4RO, 3SiO_2$. (Table VII. and Fig. 5, Curve VII.)

The formation-temperature of the pure ferrous silicate (SiO_2, 38.46; FeO, 61.54) is 1120° C., or 20° lower than that of the preceding, less siliceous, three-to-four silicate. It reaches its minimum at 1060° C., when 8 to 12 parts of CaO have replaced equivalent amounts of FeO. It then rises again, intersects the three-to-four and the bi-silicate curves with 16 per cent. CaO, coincides with the bi-silicate curve at 16 to 20 per cent. CaO, and finally rises with a further increase of CaO, but more slowly than does the bi-silicate curve.

FIG 9.

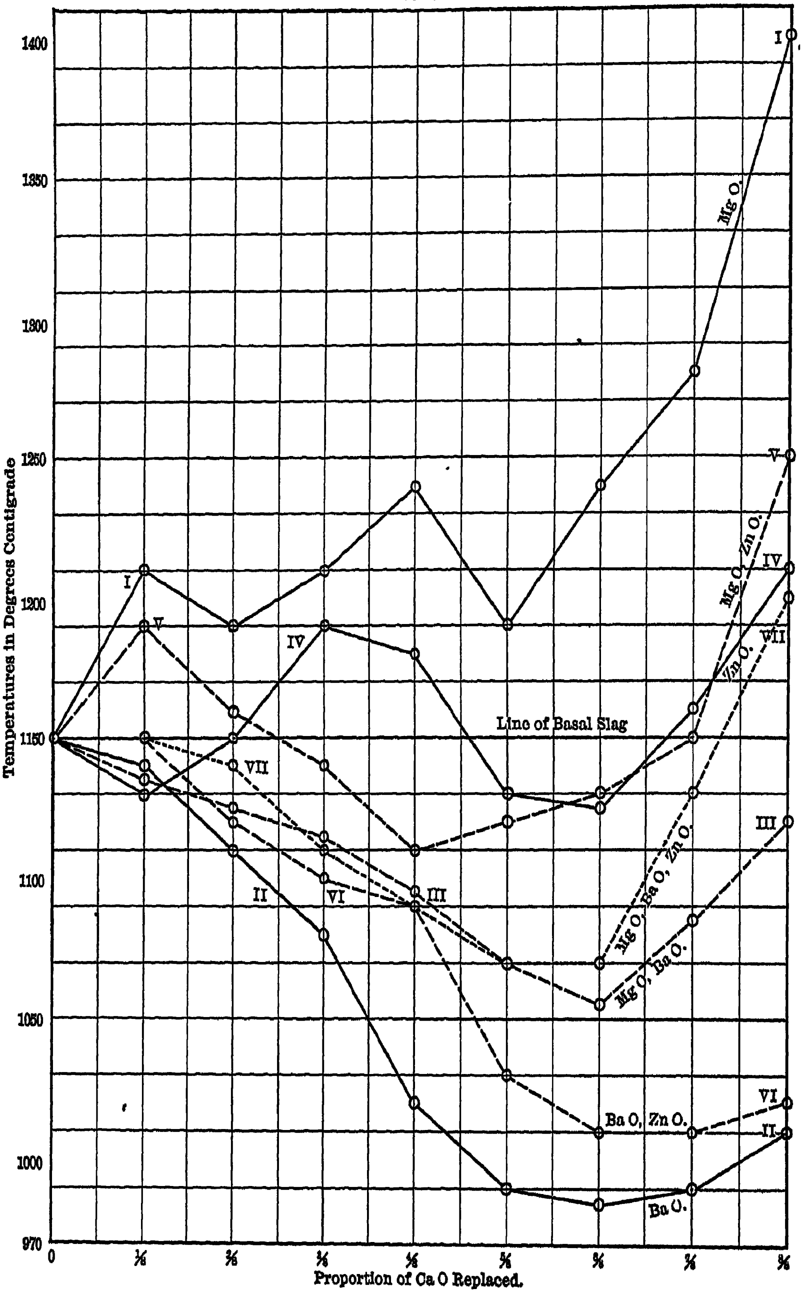


DIAGRAM SHOWING EFFECT OF REPLACEMENT OF CA O BY MG O, BA O AND ZN O.

TABLE VII.—*Formation of the Sesqui-Silicate,* $4RO, 3SiO_2$. (See Figs. 5 and 6, Curves VII. and VIIa.)

Chemical Composition of Slag.			Equivalent Per Cent. on Si (FeO, CaO).		Melting-Point.	
SiO_2. Per cent	FeO. Per cent.	CaO. Per cent.	FeO. Per cent.	CaO. Per cent.	Seger Cone. No.	Degrees, C.
38.46	61.54	0	100.00	0.00	02½	1,120
38.90	57.10	4	91.74	8.26	03	1,090
39.34	52.66	8	83.66	16.34	05½	1,060
39.78	48.22	12	75.76	24.24	05½	1,060
40.22	43.78	16	68.03	31.97	03	1,090
40.66	39.34	20	60.48	39.52	01	1,130
41.11	34.89	24	53.07	46.93	1	1,150
41.54	30.46	28	45.82	54.18	1½	1,160
41.99	26.01	32	38.73	61.27	1¾	1,165
42.42	21.58	36	31.79	68.21	3	1,190
42.87	17.13	40	24.98	75.02	6	1,250
43.31	12.69	44	18.26	81.74	11 +	1,330 +
43.75	8.26	48	11.65	88.35	......	......
44.19	3.81	52	......	......	......	......

The Bi-Silicate, RO, SiO_2. (Table VIII. and Fig. 5, Curve VIII.)

The formation-temperature of the pure ferrous silicate (SiO_2, 45.45; FeO, 54.55), the most siliceous that is made in blast-furnace work, is 1110° C., being lower than that of any of the other slags. The addition of CaO up to 8 per cent. brings it down to a minimum of 1030° C.; but with more CaO the curve is reversed and quickly ascends in the temperature-scale. While a bi-silicate slag is rarely made at present, it was a favorite slag in former years, when little if any lime was added to the ore-charge. The curve shows the low formation-temperatures of slags containing under 10 per cent. of CaO.

The acid character of these slags prevented them from attacking the acid furnace material enclosing the smelting-zone; but their fluidity was small; they ran very slowly from the furnace, and thus they were the cause of the small amounts of charge that could be put through, while they also obstructed the settling-out of the valuable products.

In comparing the different slags, it will be seen that the pure ferrous silicates always have the highest formation-temperatures; that a replacement of FeO by CaO reduces these temperatures to certain points, but that with further additions of CaO the curves are reversed, and the formation of silicates

TABLE VIII.—*Formation of the Bi-Silicate, RO, SiO_2.* (See Figs. 5 and 6, Curves VIII. and VIII*a*.)

CHEMICAL COMPOSITION OF SLAG.			EQUIVALENT PER CENT. ON Si (FeO, CaO).		MELTING-POINT.	
SiO_2. Per cent	FeO. Per cent.	CaO. Per cent.	FeO. Per cent.	CaO. Per cent.	Seger Cone. No.	Degrees, C.
45.45	54.55	0	100.00	0.00	02	1,110
46.00	50.00	4	90.67	9.33	04	1,070
46.53	45.47	8	81.55	18.45	06	1,030
47.04	40.96	12	72.65	27.35	05	1,050
47.56	36.44	16	63.87	36.13	03	1,090
48.02	31.98	20	55.45	44.55	01	1,130
48.57	27.43	24	47.09	52.91	2	1,170
49.19	22.81	28	38.80	61.20	3	1,200
49.60	18.40	32	30.92	69.08	6	1,250
50.11	13.89	36	23.09	76.91	10	1,330
50.63	9.37	40	15.41	84.59	15 +	1,430
51.14	4.86	44	7.90	92.10	......	......
51.65	0.35	48	0.58	99.42	......	......
51.73	0.00	48.27	0.00	100.00	......	......

takes place at rapidly increasing temperatures. The curves do not show, as was hoped, any simple connection between silicate-degree, percentage of lime and minimum of formation-temperature.

The Cross-Series. (Table IX. and Fig. 7.)

For the cross-series designed to show the effect of an increase of silica on the formation-temperature, a slag was chosen in which the ratio of FeO : CaO was 2 : 1, as in Table IX., which gives the chemical composition; the silicate degree, from O basic: O acid = 2 : 1 to O basic : O acid = 1 : 3.25, increasing in steps of 0.25; the numbers of the Seger cones at which the fusions took place; and the corresponding temperature in degrees C. The slags at the basic end are very fluid as soon as the formation-temperature has been reached, and are noticeably attracted by the magnet, while those at the extreme acid end fuse down slowly, carry uncombined silica, and are but slightly magnetic.

Fig. 7 represents graphically the results of the tests. It shows that from the silicate-degree 0.5 to 1.25 the formation-temperatures show only a difference of 10° C. (between 1180 and 1190° C.); then they fall, at first more rapidly than afterward, until the minimum of 1110° C. is reached with a silicate

TABLE IX.—*Formation of Slags in which the Ratio FeO : CaO = 2 : 1.*

Chemical Composition of Slag.			Silicate, Degree.	Melting-Point.	
SiO_2. Per cent.	FeO. Per cent.	CaO. Per cent.		Seger Cone. No.	Degrees, C.
18.67	54.23	27.10	0.50	3	1,190
25.61	49.60	24.79	0.75	2½	1,180
31.47	45.68	22.85	1.00	3	1,190
36.47	42.36	21.17	1.25	2½	1,180
40.80	39.46	19.74	1.50	1½	1,160
44.55	36.97	18.48	1.75	01½	1,140
47.86	34.77	17.37	2.00	02½	1,120
50.82	32.78	16.40	2.25	02¾	1,115
53.44	31.04	15.52	2.50	02	1,110
55.81	29.46	14.73	2.75	02	1,110
57.95	28.04	14.01	3.00	01	1,130
59.87	26.75	13.38	3.25	9 +	1,310 +

degree of 2.50 to 2.75; then they rise quickly to 1130° C. with the tri-silicate, and, at last, abruptly ascend the temperature-scale.

While low formation-temperatures are desirable as reducing the amount of fuel required, a slag of a silicate-degree of 2.50 to 2.75 is too viscid to flow freely. Hence, slags less siliceous and more fluid are usually made, even if the temperatures at which they are formed are higher. Thus the singulo-silicate slag SiO_2, 31.47; FeO, 45.68; CaO, 22.85 per cent., corresponding to the formula

$$6FeO, 3SiO_2 + 4CaO, 2SiO_2,$$

which is the one first made by A. Eilers,* and is one of the best slags for smelting lead ores in the blast-furnace.

Replacement of Slag-Constituents.

For the study of the effect of some of the metallic oxides which replace silica, ferrous oxide and calcium oxide in a blast-furnace slag, a singulo-silicate was chosen, as this is the leading slag made in smelting non-ferrous metals. Of the fourteen singulo-silicates given in Table II., the one containing SiO_2, 32.10; FeO, 35.90; CaO, 32.00, was selected, because, the three constituents being about equally divided, the largest range of experiment was afforded, and also because the formation-temperature, 1150° C., was low.

* See Hofman, *Lead*, 5th ed., p. 276.

In Table X. it will be seen that $\frac{1}{8}$ of a constituent has been every time replaced by an equivalent weight of one or more metallic oxides, until the latter had wholly taken the place of the original constituent.

In Figs. 8 to 10, inclusive, the original slag, called basal slag, is represented by a horizontal line corresponding to its formation-temperature of 1150° C.

FIG. 10.

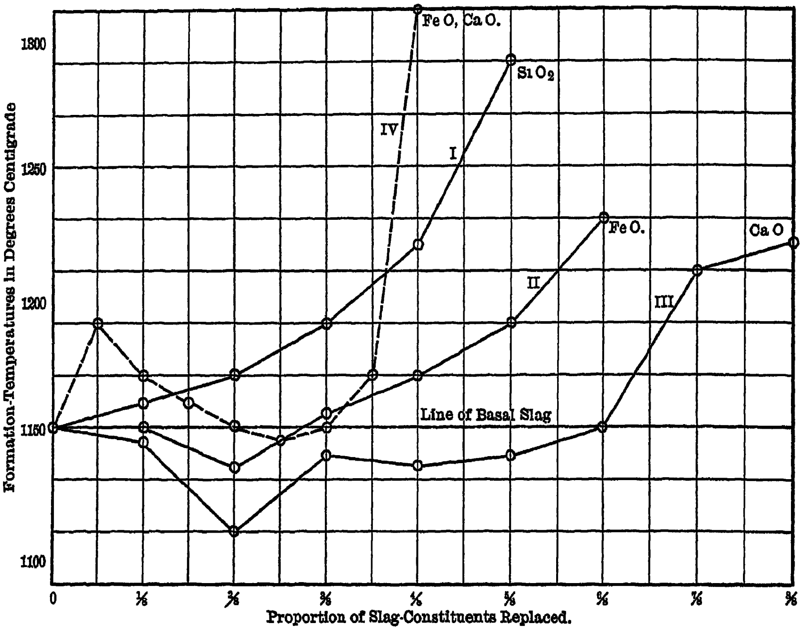


DIAGRAM SHOWING EFFECT OF REPLACEMENT OF SLAG-CONSTITUENTS BY Al_2O_3

1. *Replacement of FeO by MnO.*—Table X. gives the weight of the charges with numbers of the Seger cones and corresponding temperatures at which the slags were formed.

All these slags were watery; ranged in color from dark-gray to black (on the surface frequently dark-brown); showed a dull to slightly vitreous luster; and were noticeably attracted by the magnet.

The effect of MnO on the formation-temperature is clearly seen in Fig. 8. Manganese replacing iron raises this temperature approximately in proportion to the degree of replacement. It is usually said that manganese makes a slag more fusible, as well as more fluid; but these experiments show that the first statement will have to be reversed.

TABLE X.

Chemical Composition of Slag, in Grammes.					Melting-Point.	
SiO_2.	FeO.		MnO.	CaO.		
	Remaining.	Replaced.	Replacing.		Seger Cone. No.	Degrees, C.
32.10	35.90	.....	......	32.00	1	1,150
32.10	31.41	$\frac{1}{8}$	4.424	32.00	$1\frac{1}{2}$	1,160
32.10	26.93	$\frac{2}{8}$	8.847	32.00	2	1,170
32.10	22.44	$\frac{3}{8}$	13.27	32.00	3	1,190
32.10	17.95	$\frac{4}{8}$	17.69	32.00	$2\frac{1}{2}$	1,180
32.10	13.46	$\frac{5}{8}$	22.12	32.00	3	1,190
32.10	8.975	$\frac{6}{8}$	26.54	32.00	$3\frac{1}{2}$	1,200
32.10	4.487	$\frac{7}{8}$	30.97	32.00	$4\frac{3}{4}$	1,225
32.10	0.00	$\frac{8}{8}$	35.39	32.00	6	1,250

2. *Replacement of CaO by MgO, BaO and ZnO.*—Tables XI. to XVII., inclusive, give the charges used in making up the mixtures for replacing the CaO of the basal slag by MgO, BaO and ZnO, severally and together. In the same manner as with FeO

TABLE XI.—*The Effect of Replacing CaO with MgO.* (Fig. 9, Curve I.)

Chemical Composition of Slag, in Grammes.					Melting-Point.	
SiO_2.	FeO.	CaO.		MgO.		
		Remaining.	Replaced.	Replacing.	Seger Cone. No.	Degrees, C.
32.10	35.90	32	......	0.00	1	1,150
32.10	35.90	28	$\frac{1}{8}$	2.874	4	1,210
32.10	35.90	24	$\frac{2}{8}$	5.748	3	1,190
32.10	35.90	20	$\frac{3}{8}$	8.622	4	1,210
32.10	35.90	16	$\frac{4}{8}$	11.49	$5\frac{1}{2}$	1,240
32.10	35.90	12	$\frac{5}{8}$	14.37	3	1,190
32.10	35.90	8	$\frac{6}{8}$	17.24	$5\frac{1}{2}$	1,240
32.10	35.90	4	$\frac{7}{8}$	20.12	$7\frac{1}{2}$	1,280
32.10	35.90	...	$\frac{8}{8}$	22.99	$13\frac{1}{2}$	1,400

None of the slags appear to be very fluid. They are all opaque. On the fracture they are grayish-black, the gray increasing with the MgO to such an extent as to make the last three slags a silvery-gray. The surface shows throughout a brownish tone; the luster is vitreous; all the slags are attracted by the magnet, those rich in MgO less so than those having a high percentage of CaO.

and MnO, $\frac{1}{8}$, $\frac{2}{8}$, $\frac{3}{8}$, etc., . . . of the CaO has been replaced by the metallic oxides, giving to the mixtures 32, 28, 24, 20, etc., . . . grammes CaO, the other 4, 8, 12 etc. grammes being replaced by equivalent weights of MgO, BaO and ZnO, respec-

tively (Tables XI., XII., XIV.). Where two metallic oxides take the place of CaO, 2, 4, 6, etc., . . . grammes are exchanged for the equivalent weight of the one and the remaining 2, 4, 6 . . . grammes for that of the other (Tables XIII., XV., XVI.). With three substituting oxides, each replaces ⅓ of the grammes of CaO that are to be taken out (Table XVII.).

Fig. 9 represents graphically the results given in the tables.

TABLE XII.—*The Effect of Replacing CaO with BaO.* (Fig. 9, Curve II.)

Chemical Composition of Slag, in Grammes.					Melting-Point.	
		CaO.		BaO.		
SiO_2.	FeO.	Remaining.	Replaced.	Replacing.	Seger Cone. No.	Degrees, C.
32.10	35.90	32	...	0.00	1	1,150
32.10	35.90	28	⅛	10.94	01½	1,140
32.10	35.90	24	2/8	21.88	02	1,110
32.10	35.90	20	⅜	32.83	04½	1,080
32.10	35.90	16	4/8	43.77	07½	1,020
32·10	35.90	12	⅝	54.72	08	990
32.10	35.90	8	6/8	65.66	09¾	985
32.10	35.90	4	⅞	76.60	08	990
32.10	35.90	...	8/8	87.54	07	1,010

The slags were opaque and not very fluid. On the fracture the color is steel-gray to black; on the surface somewhat brownish. The luster is vitreous. The slags toward the end of the series are more attracted by the magnet than those at the beginning. With slags melting below 1080° C., the carbon dioxide of the barium carbonate had not all been driven off when fusion had begun.

TABLE XIII.—*The Effect of Replacing CaO with MgO and BaO.* (Fig. 9, Curve III.)

Composition of Slag, in Grammes.						Melting-Point.	
		CaO.		MgO.	BaO.		
SiO_2.	FeO.	Remaining.	Replaced.	Replacing.	Replacing.	Seger Cone. No.	Degrees, C.
32.10	35.90	32	...	0.00	0.00	1	1,150
32.10	35.90	28	⅛	1.436	5.471	01¼	1,135
32.10	35.90	24	2/8	2.874	10.94	02¾	1,125
32.10	35.90	20	⅜	4.310	16.41	02¼	1,115
32.10	35.90	16	4/8	5.748	21.88	03¼	1,095
32.10	35.90	12	⅝	7.184	27.35	04	1,070
32.10	35.90	8	6/8	8.622	32.83	05¼	1,055
32.10	35.90	4	⅞	10.06	38.30	04¾	1,085
32.10	35.90	...	8/8	11.49	43.77	02½	1,120

The slags were opaque, and did not appear to flow well. On the fracture the color at the beginning of the series was a dark steel-gray and changed to black toward the end; on the surface it was brownish. The luster was only slightly vitreous; and the slags were magnetic throughout. Slags melting below 1085° C. began to fuse before all the carbon dioxide of the barium carbonate had been driven off.

TABLE XIV.—*The Effect of Replacing CaO with ZnO.* (Fig. 9, Curve IV.)

Composition of Slag, in Grammes.					Melting-Point.	
SiO_2.	FeO.	CaO.		ZnO.		
		Remaining.	Replaced.	Replacing.	Seger Cone. No.	Degrees, C.
32.10	35.90	32	...	0.000	1	1,150
32.10	35.90	28	1/8	5.806	01	1,130
32.10	35.90	24	2/8	11.61	1	1,150
32.10	35.90	20	3/8	17.42	3	1,190
32.10	35.90	16	4/8	23.22	2½	1,180
32.10	35.90	12	5/8	29.03	01	1,130
32.10	35.90	8	6/8	34.83	02¾	1,125
32.10	35.90	4	7/8	40.64	1½	1,160
32.10	35.90	...	8/8	46.45	4	1,210

The slags showed little fluidity and became sticky toward the end of the series. They were all opaque, dark-brown to black on the fracture, and lighter brown on the surface. The luster was sub-metallic to vitreous. All the slags were magnetic.

TABLE XV.—*The Effect of Replacing CaO with MgO and ZnO.* (Fig. 9, Curve V.)

Composition of Slag, in Grammes.						Melting-Point.	
SiO_2.	FeO.	CaO.		MgO.	ZnO.		
		Remaining.	Replaced.	Replacing.	Replacing.	Seger Cone. No.	Degrees, C.
32.10	35.90	32	...	0.000	0.000	1	1,150
32.10	35.90	28	1/8	1.436	2.903	3	1,190
32.10	35.90	24.	2/8	2.874	5.805	1½	1,160
32.10	35.90	20	3/8	4.310	8.708	01½	1,140
32.10	35.90	16	4/8	5.748	11.61	03	1,110
32.10	35.90	12	5/8	7.184	14.51	03½	1,120
32.10	35.90	8	6/8	8.622	17.42	02	1,130
32.10	35.90	4	7/8	10.06	20.32	1	1,150
32.10	35.90	...	8/8	11.49	23.22	6	1,250

The fluidity of the slags varied considerably; the most fluid were Nos. 3 and 4; then followed Nos. 2 and 5, 1 and 6, 7 and 8. The slags were opaque, uniformly black on the fracture, but brownish on the surface. The luster was sub-metallic to vitreous, and all the slags were noticeably magnetic.

TABLE XVI.—*The Effect of Replacing CaO with BaO and ZnO.* (Fig. 9, Curve VI.)

Composition of Slag, in Grammes.						Melting-Point.	
SiO_2.	FeO.	CaO.		BaO.	ZnO.		
		Re-maining.	Re-placed.	Re-placing	Re-placing.	Seger Cone. No	Degrees, C.
32.10	35.90	32	...	0.00	0.000	1	1,150
32.10	35.90	28	$\frac{1}{8}$	5.47	2.903	1	1,150
32.10	35.90	24	$\frac{2}{8}$	10.94	5.805	02½	1,120
32.10	35.90	20	$\frac{3}{8}$	16.41	8.708	03½	1,100
32.10	35.90	16	$\frac{4}{8}$	21.88	11.61	03	1,090
32.10	35.90	12	$\frac{5}{8}$	27.35	14.51	06	1,030
32.10	35.90	8	$\frac{6}{8}$	32.83	17.42	07	1,010
32.10	35.90	4	$\frac{7}{8}$	38.30	20.32	07	1,010
32.10	35.90	...	$\frac{8}{8}$	43.77	23.22	07½	1,020

Although these slags formed readily, they did not flow at all at their formation-temperatures. They were opaque. The color, which was, at the beginning of the series, a dark steel-gray, became brownish-black towards the end. The luster was sub-metallic to vitreous. Slags running high in CaO were distinctly magnetic; those containing much BaO and ZnO, only slightly so. The slags forming below 1030° C. began to fuse before all the carbon dioxide of the barium carbonate had been driven off. They were spongy, and more brownish than those forming at higher temperatures.

TABLE XVII.—*The Effect of Replacing CaO with MgO, BaO and ZnO.* (Fig. 9, Curve VII.)

Composition of Slag, in Grammes.							Melting-Point.	
SiO_2.	FeO.	CaO.		MgO.	BaO.	ZnO.		
		Re-maining.	Re-placed.	Re-placing.	Re-placing.	Re-placing.	Seger Cone. No.	Degrees, C.
32.10	35.90	32	...	0.00	0.000	0.000	1	1,150
32.10	35.90	28	$\frac{1}{8}$	0.958	3.647	1.922	1	1,150
32.10	35.90	24	$\frac{2}{8}$	1.916	7.295	3.845	01½	1,140
32.10	35.90	20	$\frac{3}{8}$	2.874	10.94	5.767	02	1,110
32.10	35.90	16	$\frac{4}{8}$	3.831	14.59	7.690	03	1,090
32.10	35.90	12	$\frac{5}{8}$	4.789	18.24	9.612	04	1,070
32.10	35.90	8	$\frac{6}{8}$	5.747	21.88	11.535	04	1,070
32.10	35.90	4	$\frac{7}{8}$	6.705	25.53	13.46	01	1,130
32.10	35.90	...	$\frac{8}{8}$	7.663	29.18	15.38	3½	1,200

None of the slags are fluid: all are opaque; grayish-black on the fracture; dull brown on the surface; sub-metallic to vitreous in luster; and attracted by the magnet.

It will be seen that there is a great similarity in the general physical properties of these slags: at least, the differences are not sufficiently great to give to the several numbers of the series any special characteristics.

3. *Discussion of Temperature-Curves, Fig. 9.*—In Fig. 9 the abscissa gives in eighths the proportion of CaO replaced by the different oxides; the ordinate, the temperature in degrees C.

Curve I. (CaO replaced by MgO) shows clearly that as soon as MgO begins to replace CaO, the formation-temperature rises very decidedly above that of the basal slag, 1150° C. With $\frac{1}{8}$ of the CaO replaced, the temperature rises to 1210° C., it then sinks until $\frac{2}{8}$ is replaced (1190° C.), and rises again until $\frac{4}{8}$ has been reached (1240° C.); after a second depression to 1190° C. (with $\frac{5}{8}$ CaO replaced), it rises steadily to 1400° C., when MgO has been substituted for all of the CaO. While the curve shows rises and falls, it always remains above the line of the basal slag—a fact which explains the aversion of many smelters to the use of a dolomitic limestone as flux.

Curve II. (CaO replaced by BaO) shows that, as MgO raises the formation-temperature, so BaO lowers it, only that the curve shows more regularity. The melting-point descends steadily with the increase of BaO, until $\frac{6}{8}$ of the CaO has been thus replaced, when a minimum is reached at 985° C.; but even when all the CaO has been taken away, the temperature rises only to 1010° C. The curve shows BaO to be a powerful flux. This fact will be again seen clearly further on, in the results of combining BaO with other refractory oxides, as it straightens out their curves and lowers their melting-points (see curves III., VI. and VII.).

Curve III. (CaO replaced by MgO and BaO) shows that MgO, replacing CaO, raises the formation-temperature of the basal slag, and gives an irregular curve; but as soon as BaO is substituted for part of the MgO, the curve becomes more regular, and the melting-point is decidedly lowered, or, in other words, BaO promotes the slagging of MgO. Thus, when $\frac{1}{8}$ of the CaO was replaced by MgO alone, the formation-temperature rose from 1150° C. to 1210° C.; but when one-half of the MgO is replaced by BaO, the temperature sinks to 1135° C., and continues to sink with the increase of the two constituents until the minimum has been reached at 1055° C., with a substitution of $\frac{6}{8}$ of the CaO. After that, the temperature rises, but remains below the curve of the basal slag.

Curve IV. (CaO replaced by ZnO) illustrates by its peculiar form some of the difficulties that smelters encounter in treating

zincose ores. At first, the melting-point is lowered ($\frac{1}{8}$ replacement giving 1130° C.); but it then rises, crosses the curve of the basal slag, and reaches a first maximum at 1240° C. when ZnO has been substituted for $\frac{4}{8}$ of the CaO; then it descends below the line of the basal slag to a minimum, at 1125° C.; and finally rises quickly to the second and last maximum, at 1210° C. Some metallurgists hold that most of the ZnO is held in igneous solution by a slag; others (*e.g.* Dr. Iles*), that most, if not all, of the ZnO is slagged, as are the other bases. The very irregular form of curve IV. seems to indicate that both opinions have their justification, *i.e.*, that the presence or absence of other metallic oxides, besides FeO and CaO, may promote or obstruct the scorification of ZnO. The curve, taken by itself, indicates that in some cases more ZnO was slagged than in others.

Curve V. (CaO replaced by MgO and ZnO) seems to bear out the opinion held by smelters generally that MgO and ZnO in a slag intensify its refractory properties. MgO alone (curve I.) raised the formation-temperature throughout, though not uniformly; ZnO (curve IV.) sometimes raised it and sometimes lowered it; MgO and ZnO do not give a resultant average of their peculiarities; sometimes one predominates, sometimes the other. In curve V., with $\frac{1}{8}$ and $\frac{2}{8}$ replacement, the temperature follows the magnesia-curve (I.); with $\frac{2}{8}$ to $\frac{5}{8}$ replacement, it goes just in the opposite direction of the magnesia—as well as of the zinc-oxide curve (IV.), and with $\frac{5}{8}$ to $\frac{8}{8}$ replacement it has a tendency to follow the zinc-oxide curve.

Curve VI. (CaO replaced by BaO and ZnO) clearly illustrates the great effect of BaO as a flux. Its general trend is similar to that of the BaO-curve (II.), only the temperatures lie a little higher. The great irregularity of the zinc-oxide curve has been nearly wiped out, or, in other words, BaO greatly promotes the slagging of ZnO. As the curve shows, $\frac{1}{8}$ replacement leaves the melting-point of the basal slag unchanged; further substitutions lower the melting-point until the minimum of 1010° C. is reached, with $\frac{6}{8}$ of the CaO replaced. In the lowering of the temperature, the two curves (VI. and II.) are first approximately parallel, as far as $\frac{2}{8}$ replacement; then the refractory nature of ZnO begins to assert itself, until $\frac{4}{8}$ of

* *School of Mines Quarterly*, xix., p. 197.

the CaO has been removed; but further on it yields again, more and more, to the fluxing-power of BaO.

Curve VII. (CaO replaced by MgO, BaO and ZnO) is another instance of the fluxing power of BaO. The curve of MgO-ZnO (V.) showed ups and downs which could not be well harmonized with either the curve of MgO (I.) or that of ZnO (IV.); but as soon as BaO is added we obtain a curve that is quite regular. Thus, with $\frac{1}{8}$ replacement, the formation-temperature of the basal slag is not changed; but with further reductions of CaO, the temperature is steadily lowered to the minimum of 1070° C., with a replacement of $\frac{5}{8}$ to $\frac{6}{8}$ of the CaO, after which it quickly rises to a maximum of 1200° C. The refractory effect of MgO is clearly shown by curve VII., which, with one exception, always indicates higher temperatures than curve VI.

4. *Replacement of Slag-Constituents by Al_2O_3.*

Tables XVIII. to XXI., inclusive, give the charges used in studying the effects produced on the formation-temperature of a slag by the replacement with Al_2O_3 of the three constituents SiO_2, FeO and CaO. The general plan of substitution is the same as was followed in Tables XI. to XVII. Fig. 10 gives a graphical representation of the results.

TABLE XVIII.—*The Effect of Replacing SiO_2 with Al_2O_3.* (Fig. 10, Curve I.)

Composition of Slag, in Grammes.					Melting-Point.	
SiO_2.		Al_2O_3.	FeO.	CaO.		
Remaining.	Replaced.	Replacing.			Seger Cone. No.	Degrees, C.
32.10	...	0.000	35.90	32	1	1,150
28.09	$\frac{1}{8}$	4.525	35.90	32	$1\frac{1}{2}$	1,160
24.07	$\frac{2}{8}$	9.050	35.90	32	2	1,170
20.06	$\frac{3}{8}$	13.57	35.90	32	3	1,190
16.05	$\frac{4}{8}$	18.10	35.90	32	$4\frac{1}{2}$	1,220
12.04	$\frac{5}{8}$	22.62	35.90	32	8	1,290
8.025	$\frac{6}{8}$	27.14	35.90	32	...	......
4.012	$\frac{7}{8}$	31.66	35.90	32	...	......
0.000	$\frac{8}{8}$	36.20	35.90	32	...	......

All these slags show a lack of fluidity. They are opaque, from dark-gray to black on the fracture, and dull reddish-brown on the surface. The last slag of which the formation-temperature could be determined had a dark steel-gray sur-

face, which is characteristic of all slags running very high in Al_2O_3. The luster of all the slags was dull to slightly vitreous; and all were attracted by the magnet; but the magnetism diminished as Al_2O_3 increased.

TABLE XIX.—*The Effect of Replacing FeO with Al_2O_3.* (Fig. 10, Curve II.)

Composition of Slag, in Grammes.					Melting-Point.	
SiO_2.	FeO.		Al_2O_3.	CaO.		
	Remaining.	Replaced.	Replacing.		Seger Cone. No	Degrees, C.
32.10	35.90	...	0.000	32	1	1,150
32.10	31.41	$\frac{1}{8}$	2.121	32	1	1,150
32.10	26.93	$\frac{2}{8}$	4.242	32	01¼	1,135
32.10	22.44	$\frac{3}{8}$	6.363	32	1¼	1,155
32.10	17.95	$\frac{4}{8}$	8.485	32	2	1,170
32.10	13.46	$\frac{5}{8}$	10.586	32	3	1,190
32.10	8.975	$\frac{6}{8}$	12.72	32	5	1,230
32.10	4.487	$\frac{7}{8}$	14.84	32	...	......
32.10	0.000	$\frac{8}{8}$	16.97	32	...	......

These slags are all fairly fluid, especially the two melting at 1155° and 1170° C. They are opaque; dull brown on the fracture when little Al_2O_3, and dark-gray when much Al_2O_3, is present; and dull reddish-brown on the surface. The luster is dull to slightly vitreous; and magnetism is noticeable, especially with a low percentage of Al_2O_3.

TABLE XX.—*The Effect of Replacing CaO with Al_2O_3.* (Fig. 10, Curve III.)

Composition of Slag, in Grammes.					Melting-Point.	
SiO_2.	FeO.	CaO.		Al_2O_3.		
		Remaining.	Replaced.	Replacing.	Seger Cone. No.	Degrees, C.
32.10	35.90	32	...	0.000	1	1,150
32.10	35.90	28	$\frac{1}{8}$	2.430	01¾	1,145
32.10	35.90	24	$\frac{2}{8}$	4.860	02	1,110
32.10	35.90	20	$\frac{3}{8}$	7.290	01½	1,140
32.10	35.90	16	$\frac{4}{8}$	9.720	01¼	1,135
32.10	35.90	12	$\frac{5}{8}$	12.15	01½	1,140
32.10	35.90	8	$\frac{6}{8}$	14.58	1	1,150
32.10	35.90	4	$\frac{7}{8}$	17.01	4	1,210
32.10	35.90	...	$\frac{8}{8}$	19.44	4½	1,220

None of the slags are fluid: on the contrary, they have a tendency toward viscosity, especially with a high percentage of Al_2O_3. They are opaque, grayish-black to black on both fracture and surface, and slightly vitreous in luster. The magnet attracts them somewhat—those high in Al_2O_3 less than those high in CaO.

TABLE XXI.—*The Effect of Replacing FeO and CaO with Al_2O_3.* (Fig. 10, Curve IV.)

Composition of Slag, in Grammes.						Melting-Point.	
SiO_2.	FeO.		CaO.		Al_2O_3.		
	Re-maining.	Re-placed.	Re-maining.	Re-placed.	Re-placing	Seger Cone. No.	Degrees, C.
32.10	35.90	...	32	...	0.000	1	1,150
32.10	33.66	$\frac{1}{16}$	30	$\frac{1}{16}$	2.275	3	1,190
32.10	31.41	$\frac{2}{16}$	28	$\frac{2}{16}$	4.550	2	1,170
32.10	29.17	$\frac{3}{16}$	26	$\frac{3}{16}$	6.825	$1\frac{1}{2}$	1,160
32.10	26.93	$\frac{4}{16}$	24	$\frac{4}{16}$	9.100	1	1,150
32.10	24.69	$\frac{5}{16}$	22	$\frac{5}{16}$	11.37	$01\frac{1}{4}$	1,145
32.10	22.44	$\frac{6}{16}$	20	$\frac{6}{16}$	13.65	1	1,150
32.10	20.20	$\frac{7}{16}$	18	$\frac{7}{16}$	15.92	2	1,170
32.10	17.95	$\frac{8}{16}$	16	$\frac{8}{16}$	18.20	9	1,310

None of these slags are very fluid: the mixtures with 9.10 and 11.37 grammes of Al_2O_3 were the most so; mixtures with 15.92 and 18.20 grammes of Al_2O_3 least so. The slags were opaque; grayish-brown to black on the fracture; and dark-brown, more or less tinged with red, on the surface; sub-metallic to vitreous in luster, and all noticeably attracted by the magnet.

The general physical properties show no characteristic points, except that some slags appear to be more fluid than others. If the formation-temperatures of these slags are favorable, they deserve consideration in the smelting of aluminous ores.

5. *Discussion of Temperature-Curves, Fig.* 10.—In Fig. 10 the abscissa again represents the proportions of the different constituents replaced by Al_2O_3, and the ordinate the temperature in degrees C.

Curve I. (SiO_2 replaced with Al_2O_3) shows that the replacement of SiO_2 with Al_2O_3 raises the formation-temperature of the basal slag in an increasing ratio: $\frac{1}{8}$ replacement giving 10° C.; $\frac{2}{8}$ replacement, 20° C.; $\frac{3}{8}$ replacement, 40° C.; $\frac{4}{8}$ replacement, 70° C.; and $\frac{5}{8}$ replacement, 140° C. increase of this temperature. Mixtures with a higher percentage of Al_2O_3 could not be fused.

The curve proves that, in treating aluminous ores, Al_2O_3 cannot be simply substituted for SiO_2, as has often been advocated, without raising the melting-point. The contrary procedure will be the right one, namely, that of keeping the percentage of SiO_2 high.

Curve II. (FeO replaced with Al_2O_3) shows that, first, with $\frac{1}{8}$ replacement, Al_2O_3 does not change the formation-tempera-

ture of the basal slag. More Al_2O_3 first lowers it somewhat (to 1135° C. with $\frac{2}{8}$ replacement); but raises it again, quickly and pretty uniformly, until, after a replacement of $\frac{6}{8}$ of the FeO, a mixture is obtained which will not fuse at 1430° C., the temperature indicated by Seger cone No. 15.

The curve shows that only small portions of the FeO can be replaced by Al_2O_3 without raising the formation-temperature to too high a point. It proves also that the rule, to keep both SiO_2 and CaO high in the presence of Al_2O_3, can be applied within narrow limits only.

Curve III. (CaO replaced with Al_2O_3) shows that by substituting Al_2O_3 for CaO, the melting-point of the basal slag is lowered until $\frac{6}{8}$ of the CaO has been replaced, when the formation-temperature rises suddenly. With the exception of the great depression of the curve to 1110° C., when $\frac{2}{8}$ of the CaO has been replaced, the lowering of the formation-temperature by progressive replacement up to $\frac{6}{8}$ averages only 10° C. This proves that figuring Al_2O_3 into a slag as replacing CaO is a justifiable proceeding. A combination of curves I. and III. suggests that if part of the SiO_2 and CaO were replaced by Al_2O_3, the formation-temperature of the basal slag would remain the same. This is a favorite method in the smelting of the highly aluminous Cripple Creek gold-ores in Colorado lead blast-furnaces, and gives most satisfactory results.

Curve IV. (FeO and CaO replaced with Al_2O_3) is so irregular in general trend, and so different from the three preceding curves, as to suggest that the substitution of Al_2O_3 for both FeO and CaO has no practical value. By replacing only $\frac{1}{16}$ of FeO and CaO with Al_2O_3, the formation-temperature is raised 40° C.; upon increasing the Al_2O_3 to $\frac{5}{16}$, the temperature falls below the line of the basal slag, coming to a minimum at 1145° C. With further addition of Al_2O_3, it rises suddenly, reaching 1310° C., with $\frac{8}{16}$ of FeO and CaO replaced by Al_2O_3.

VIII. Conclusion.

In all the experiments only the formation-temperatures were carefully measured, as above described. As far as was possible with the small samples, the general physical properties, including fluidity, were observed. Many mixtures which were changed into slags at comparatively low temperatures may not be suited

for practical slags on account of their viscosity at the temperatures at which they were formed; and would require considerable superheating to make them sufficiently fluid to run easily and permit a satisfactory separation of the valuable end-product or intermediary product from the waste.

The Equipment of Metallurgical Laboratories.

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(New York Meeting, February, 1899.)

WHAT should be the chief aim of a metallurgical laboratory? Before answering this, let us ask, What should be the chief aim of metallurgical instruction? Taking a definite case, that of the iron blast-furnace, should we chiefly teach the methods of bosh- and tuyere-cooling, of storing and assembling materials, of removing the iron and cinder, of firing boilers and cleaning stoves? Or should we aim chiefly to lay clear and bare the nature of the reactions which occur in the blast-furnace, the reason why changes in the rate of driving, in the blast-temperature, in the composition of the cinder, cause their known effects? Shall we chiefly describe or explain? Shall we teach chiefly the looks or the reasons?

Put thus, the question admits but one answer. Hours of labored description at a technical school give a less true and clear view of actual metallurgical operations than a brief visit to metallurgical works. If in my teaching I take the far more laborious course and lay so very great stress on explanation and so little on description that I seem to err on that laborious side and not to give description enough, the student will quickly make up for my lack of description in his first weeks in the works; he will there learn quickly and easily what I could have described only obscurely and with labor. Details of practice are learned easily and retentively in the works, but with difficulty and slowly at school.

With the principles, and especially the chemical principles of metallurgy, the reverse is true. The works have little facility for teaching them; the school has every facility. The place then for explaining, for teaching principles, is the school. But,

of course, in order to explain, the school must first describe; for the explanation sinks hardly deeper than an algebraic theorem unless the thing, the furnace, the operation to be explained, is clear and living in the mind. Before I can explain effectively the phenomena of the blast-furnace my students must have in their minds a clear conception of the blast-furnace itself, of its construction and operation. This conception may be in skeleton, but it must be clear. So, while we should certainly describe as vividly as possible, and bring to our aid every device of model, colored diagram and demonstration, yet we should recognize clearly that this description is only a necessary means to a far more important end—that of giving a conception of the blast-furnace and some acquaintance with it, not chiefly for that conception and acquaintance themselves, but so that on them as a foundation we may build that superstructure which is the true object of our instruction, an understanding of the philosophy of the blast-furnace. A far clearer conception and better acquaintance with the blast-furnace than the school can possibly give will be given by the first few days at a blast-furnace itself; but not so with an understanding of its philosophy. This is given most quickly, clearly and easily by those whose life's work is to explain, by those who are chosen for their powers of explanation, and it is to be had only slowly and painfully in the works themselves.

So let us recognize that, in case of the iron blast-furnace, the at best slight and superficial familiarity with the conditions of practice which descriptions at school can give is—*pace* my excellent friends who lay such stress on the practicalness of education—of secondary importance in and for itself, but necessary as the basis of explanation.

Turning, now, to the metallurgical laboratory, let us for a moment consider the cupola or shaft-furnace as a means of instruction. We shall, I believe, soon have one at Columbia; for it has great educational value, though not chiefly of the kind which is often attributed to it. A friend for whose opinion I have very great respect writes me: "With a small roaster and shaft-furnace a student can be taught more, and can gain a clearer insight into metallurgical reactions in a week, than three months of lecture-room instruction will accomplish." I believe that this opinion is very general. It comes near the truth, but yet is far enough from the truth to be dangerously misleading.

The belief that work at these furnaces can, in and by itself, give this clear insight into metallurgical reactions tallies ill with the complete ignorance of those reactions which intelligent and literate workmen may have after years of this work. What is meant, probably, is that such work, in that it acquaints the student with roasting-operations, making them a visible and clearly conceived thing, lays a firm foundation on which we may build the thing really important for the school to create—an understanding of their philosophy. This is true, the other false. Let an example explain my meaning.

The handling of the molten products of the shaft-furnace calls for certain special ways of procedure. They must not chill, nor must they cut through their containing walls. They must be tranquil enough to separate well by gravity. Look through the tuyeres and you get some notion, alas! a crude one, of the conditions within. Note how the charge settles, how the throat flames. Purposely increase and diminish the ratio of coke to mine, or the fusibility of the slag, and you learn the symptoms of excessive heat and reduction, and of chilling up. Purposely induce other ailments, and you see their symptoms. You get a general acquaintance with the conditions and symptoms of the shaft-furnace, such an acquaintance as the man from Mars would get of humanity by looking in at our windows. But the direct acquaintance which you get is with a few phenomena, not with the underlying principles. The man from Mars learns some human customs, but the deep underlying motives he will learn more quickly from the writings of some master—a George Eliot, a Thackeray, a Shakespeare—than from such inspection. Bell's writings taught far more of the principles of the blast-furnace in a month than intimacy with practice for many decades had taught his predecessors.

In short, while prizing the cupola-furnace as an instrument for study, I do not see clearly that it directly teaches principles. But if it teach no principles, wherein is its value? It gives the student such a smattering of practice that he impresses superficial people with the "practicalness" of his education. But will not that which impresses them be found to mean chiefly that he has acquired at school, with great difficulty, the sort of superficial smattering of practice which he will easily get in his first week in the works themselves? After the student has been out of school for two years, how much will he benefit by

the fact that in school he anticipated with great labor his first weeks of practical experience? Will he then, or ten years later, be better off for that anticipation than one who, in school, did not thus anticipate, but instead made great efforts to pierce deep into the principles which underlie his art? The purpose of a school is not to anticipate practice, but to give what practice, as such, so often does not, a knowledge of the principles underlying practice. Here, then, we have an inefficient anticipation, calling for a far greater expenditure of energy than the works-experience which it seeks to anticipate.

But there is another and far more efficient form of anticipation. As the symptoms of human disease are studied better in the hospital than in the ball-room or gymnasium, in sickness than in health, so the laboratory offers certain advantages over the works for studying the symptoms of the diseases of the cupola; for in the laboratory there is little difficulty in inducing most serious diseases, in a variety and in a degree of aggravation not quickly to be matched in the works. Here, then, we have a very efficient form of anticipation of practice, showing quickly and in an exaggerated form, as with a microscope, the symptoms which works-experience might show only at long intervals, and in a form not easily recognized and analyzed because not exaggerated. Here lies chiefly, I take it, the really practical value of such instruction, a value which I do not question, and would not belittle in contending that a yet far more valuable result of this instruction is the foundation which it lays for our explanations of those diseases of the cupola, their causes, symptoms, and cure. And what is true of their illnesses is true also of their various types of healthy existence.

At most of the great mining schools of Europe, some of them led by really great educators, metallurgical laboratories are viewed with great distrust. The opinions of these men are not to be brushed aside as senile or antiquated. And I have wondered whether their distrust is not due to the stress which has been put on the former or "inefficient anticipation" side of metallurgical laboratory-work as it exists, and to overlooking more important sides of that work, one of which admits, I believe, of far greater development than it has yet attained. To this I shall return shortly.

The public, and even the educated practitioner, so easily

The public, and even the educated practitioner, so easily losing sight of the essential aims and conditions of [illegible]. tends always to overvalue the visible signs of education, such as the laboratory, and to undervalue the invisible but paramount parts, the thoughts made clear, the interest or even enthusiasm kindled. And we who have laboratories are ever exposed to the temptation to practice on that foible; for it is so easy to make a great show with laboratories, and so slow to prove that our graduates see clearly and work enthusiastically.

It may be asked whether students are not intentionally given at school such proficiency in the practical work of chemical analysis and of surveying that they may immediately on graduating begin to earn money by those arts; and, if so, why not in metallurgy also? In analysis and surveying this concession is reluctantly made, with the apology that, while this proficiency is no part of education as such, it is expedient, because there are many students who would not be justified in incurring the expense of a long technical education unless there were a good prospect of immediate remunerative work at its end. I believe that it is expedient to give the student metallurgical instruction parallel with this, *i.e.*, of immediate bread-winning value, such as skill in manipulating the Le Chatelier pyrometer, the Mahler calorimeter, etc.; in short, the instruments of precision of metallurgy. These may give him an immediate value to his employer. This is not anticipating his practice in the works, for he will not, in general, in the works find himself surrounded by those expert with these instruments. But I do not think that the trifling familiarity with the manipulations of the cupola or roasting-furnace which the school can give can greatly increase the young graduate's immediate usefulness. He can at the works immediately begin using the Le Chatelier pyrometer, and thus be of immediate use to his employer; but the slight knowledge of the manipulation of the cupola-furnace which he can get at school does not to any like degree increase his immediate or initial usefulness in manipulating that furnace.

Where, then, is the chief value of the metallurgical laboratory? I have already indicated it. That work acquaints us with the behavior and needs of the molten products and of the sinking charge, with the travel of the gases, the distribution of the heat, and with the general look of things, of molten slag, matte and metal, the gradual darkening and re-brighten-

ing of the tuyeres as we purposely freeze the furnace up, and again melt it out. It acquaints—that is its merit. It makes the conditions of these furnaces more real and concrete than they can readily be made by oral description; it gives the student the sort of acquaintance and respect for their mechanical difficulties which he gets for fire when he burns his fingers. In that it makes these furnaces, their operations, their mechanical difficulties, and the symptoms of their diseases, concrete to the student's mind, and in that it changes them from mere algebraic ideas to real acquaintances, it facilitates and clarifies very greatly the explanation of those principles which it is the chief aim ot metallurgical instruction to lay bare. This facilitating and clarifying, I take it, is the end towards which study with such furnaces may be a most precious means; and what I have said of cupola-furnaces I believe holds true, *mutatis mutandis*, of the other common forms of metallurgical laboratory apparatus.

In thus attempting to discriminate and to define the proper function of the cupola-furnace, which I have selected as one type of metallurgical laboratory apparatus, in trying to show that it is of great use as a foundation for explanation, though of but secondary value for anticipating practice, I am not its opponent but its supporter. To admit freely the exaggeration or weakness of exaggerated or essentially weak claims made for it is not to oppose it; to uphold the validity of really valid ones is to support it. I believe that it is an extremely important aid to metallurgical education.

I have referred to developing that side of metallurgical laboratory work which serves rather to facilitate the exposition of principles than to give practical knowledge; this, indeed, is the reason for the existence of this paper. The student of chemistry, even of industrial chemistry, does not carry out operations on a manufacturing scale. He is not studying in his laboratory administrative methods. If, as I have maintained, the chief end of metallurgical laboratory-instruction is to facilitate and clarify the exposition of metallurgical principles, there is a very great amount of this work which can be carried out by means of desk-experiments like those of the chemical laboratory, without any furnaces at all, and there is another very great part which requires furnaces of only very moderate size.

For instance, operating on pieces of wire, say $\frac{3}{32}$ of an inch in diameter, the student can not only study at his desk the phenomena of hardening, tempering and annealing, the other forms of heat-treatment of iron, steel, and the alloy steels, the relation between the influence of the various forms of heat-treatment and the composition of the metal, the effect of cold-work and the progress of the modification of that effect by annealing; but he can there, with very simple apparatus, make exact quantitative study of these and many like matters. He can, still at his desk, and, if you wish, in classes of a hundred, carry out some of the wet processes for copper; with simple, inexpensive wooden roll-trains and some ingots of plastic wax he can more readily get an insight into the principles of roll-turning than if he operated on white-hot metal. The advanced student can go far in the metallography of iron and of the alloys of the other metals, and in the use of pyrometers and calorimeters. None of these operations need furnaces at all; the Bunsen lamp, reinforced, perhaps, by an inverted crucible, or by an electric heating-device on the desk, giving the required temperature.

Again, with furnaces of moderate size and cost he can practice almost all reverberatory roasting-operations; for it is hard to see how a hearth 10 by 100 feet can teach more of the principles of roasting than one 18 by 24 inches. So with relatively inexpensive furnaces he can study the chilling of cast-iron, the effect of sulphur, silicon and manganese on the fracture and the transverse strength of cast-iron, the annealing of malleable castings, the casting of alloys, the fusibility and desulphurizing power of slags, welding, desilverizing lead, copper-refining, the shrinkage of refractory materials and their behavior towards various slags. It seems to me that the extent, variety and educational value of simple experiments which, if provided with well-drawn instructions, the student can perform with cheap and unpretentious laboratory-equipment, has been overlooked in the attempt to reproduce with great labor the metallurgical processes themselves.

This is especially true of the metallurgy of iron and steel. If with great difficulty we can carry out the Bessemer, the open-hearth and the crucible processes in a laboratory, and there laboriously anticipate the early weeks of practice, it is

doubtful whether in doing this we can illustrate as clearly and as fully the principles underlying those processes as we can by well-devised small-scale laboratory-experiments. And the processes of heat-treatment and the properties of steels, both normal and alloy, of various compositions, can be very easily and fully studied by desk-experiments, or at most by experiments with very small furnaces.

Up to this point I have considered laboratory-work for undergraduate students only. But I believe that it is well to provide for advanced students, and even for experienced practitioners who, for one reason or another, may wish to investigate metallurgical problems. One of the first things to suggest itself for this purpose is apparatus large enough to test proposed processes on a full working scale. As other institutions of learning, and also some private concerns, now offer such apparatus to the public, it seems more for the common interest that our first step should be, not to duplicate what the public already has, but to devise and provide something additional. On this account our earliest installations, in so far as they are designed for advanced students, aim particularly to give them the means of experimenting with great accuracy rather than on great quantities. For instance, we aim to provide furnaces in which high temperatures may, by means of incandescent as distinguished from arc electric heating, be quickly reached and accurately controlled and measured. Indeed, we connect all our furnaces through a switch-board with one of our Le Chatelier pyrometers, massively mounted, a sort of nervous center for the whole place.

In developing the present beginning of a metallurgical laboratory for the Columbia School of Mines the aim has been, for the reasons which I have just given, to provide, first, for a great variety of small-scale or desk-experiments and experiments with small furnaces, rather than for large-scale work of the cupola-furnace type; and second, for accurate work by advanced students. In both these directions we have made a beginning. We confidently hope to push this development much farther, and later to add a cupola-furnace, and perhaps other large furnaces.

The Effect of Heat-Treatment Upon the Physical Properties and the Microstructure of Medium-Carbon Steel.

BY ROBERT GORHAM MORSE, JAMAICA PLAIN, MASS.

(California Meeting, September, 1899.)

I.—INTRODUCTORY.

THIS paper presents the results of an investigation made in the metallurgical laboratory of Columbia University, New York City.

The object of the investigation was to determine how the tensile strength, the elastic limit, and the size of the grain, of a pure medium-carbon steel are affected by heating to successive temperatures between 500° and 1300° C., with slow cooling therefrom.

Since Dr. Sorby's first investigations into the microstructure of steel, the study of the subject has been continued by Professor Martens, Mr. F. Osmond, Professor Arnold, Professor Howe, Mr. A. Sauveur, Mr. J. E. Stead, and many others. Among many valuable and interesting papers I mention the following as having a special bearing upon this investigation.*

"Microstructure of Steel," by Albert Sauveur, *Trans.*, xxii., 546 (1893); "Microscopic Metallography," by F. Osmond, *Trans.*, xxii., 243 (1893); "The Microstructure of Steel and the Current Theories of Hardening," by Albert Sauveur, *Trans.*, xxvi., 863 (1896); "The Crystalline Structure of Iron and Steel," by John Edward Stead, *J. Iron and Steel Inst.*, 1898.

II.—STATEMENT OF EXPERIMENTS.

Through the kindness of Mr. N. Lilienberg, New York City, round rods $\frac{3}{4}$ of an inch in diameter were obtained, which had been rolled from one ingot. The analysis of the steel was as follows:

C, 0.343; Si, 0.027; Mn, 0.221; P, 0.0266; S, 0.0037 per cent.

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* A full list of the papers which have appeared on the subject is given in the *Metallographist*, April, 1898, p. 168.

Pieces 1 ft. long were heated to the following temperatures:

500° C	680°	800°	1200°x
600°x	687°	900°x	1300°
646°	700°	1000°	
654°	725°	1100°	

Pieces were also heated to the respective temperatures marked x and held there for periods of one-half hour, one hour, and three hours. Heatings were made in a gas-furnace, the bars being enclosed in a wrought-iron tube to equalize the temperature, and to prevent oxidation. As soon as the desired temperatures had been reached, the bars were removed from the furnace and imbedded in lime to ensure a slow and uniform rate of cooling. A Le Chatelier thermo-electric pyrometer was used to record the temperatures. The bars were then tested for tensile strength and elastic limit in a Riehlé testing-machine. The latter was determined only by the drop of the beam. The figures are therefore only approximate, as the drop was not always well-marked. After testing, a section was cut off the end of each specimen, polished, etched with nitric acid, and examined under the microscope. Microphotographs were then taken with perpendicular illumination. The ferrite appears light and the pearlyte dark.

The area of the grains of ferrite was next determined in the following manner. The number of grains in a measured area on a photograph was counted, taking the average of as many different areas as possible. Reducing this area to actual size by dividing by the area-magnification, we can determine the average area of a grain of ferrite, if we know what percentage of the measured area is ferrite, by dividing by the number of grains counted. Now the theoretical percentages by weight of ferrite and pearlyte in any carbon-steel can be calculated. Following the method described by Mr. Sauveur in his paper of 1896 (mentioned above), steel of 0.343 per cent. carbon is found to contain about 58 per cent. ferrite (the percentage of ferrite would be slightly larger in a very pure steel, and slightly smaller in a less pure one).

Assuming the specific gravities* of ferrite and pearlyte to be 7.90 and 7.84 respectively, the percentage of ferrite by area is found to be 58.17 per cent. Therefore:

* *Metallurgy of Steel*, H. M. Howe, p. 257.

$$\frac{\text{Measured area x } 0.5817}{\text{Number of grains counted}} = \text{Average area of grain.}$$

Photographing with a higher magnification would have been

FIG. 1.

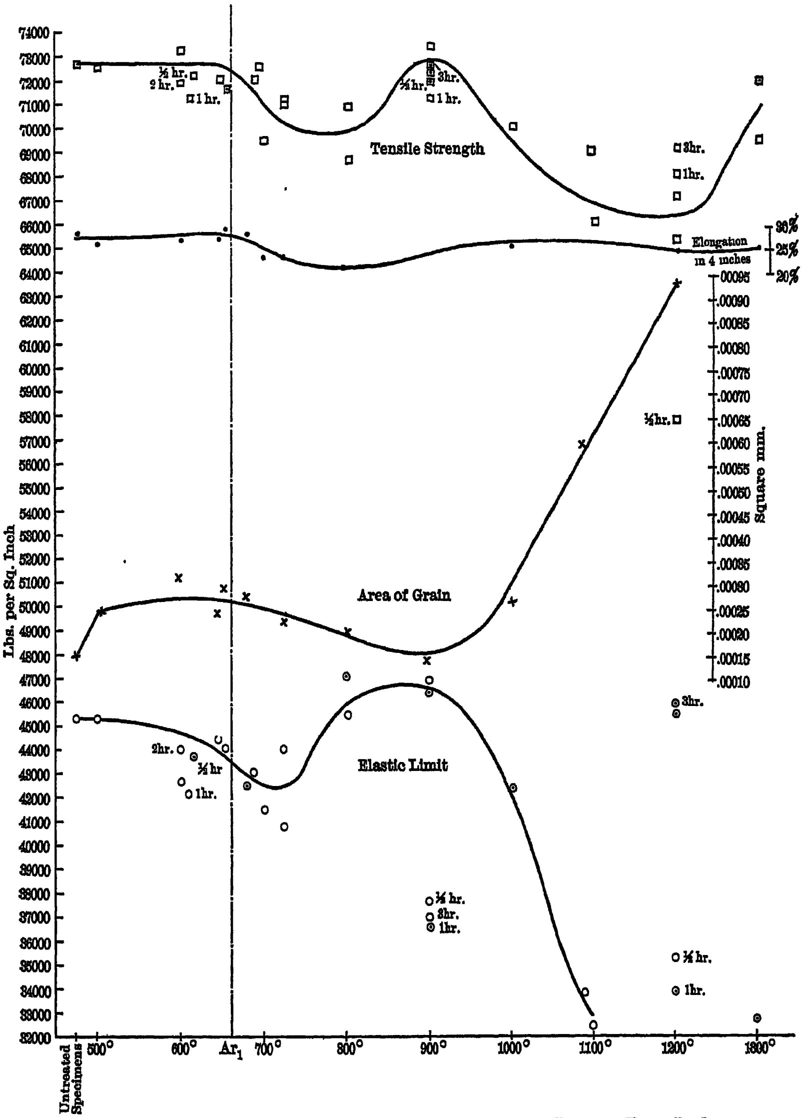


Diagram Showing the Effects of Heat-Treatment upon Steel, as Described.

interesting in a number of instances. Higher-power objectives were tried, but without success, as the field could not be properly focussed.

The results of our observations are plotted on Fig. 1, in which the figures for tensile strength, elastic limit, elongation,

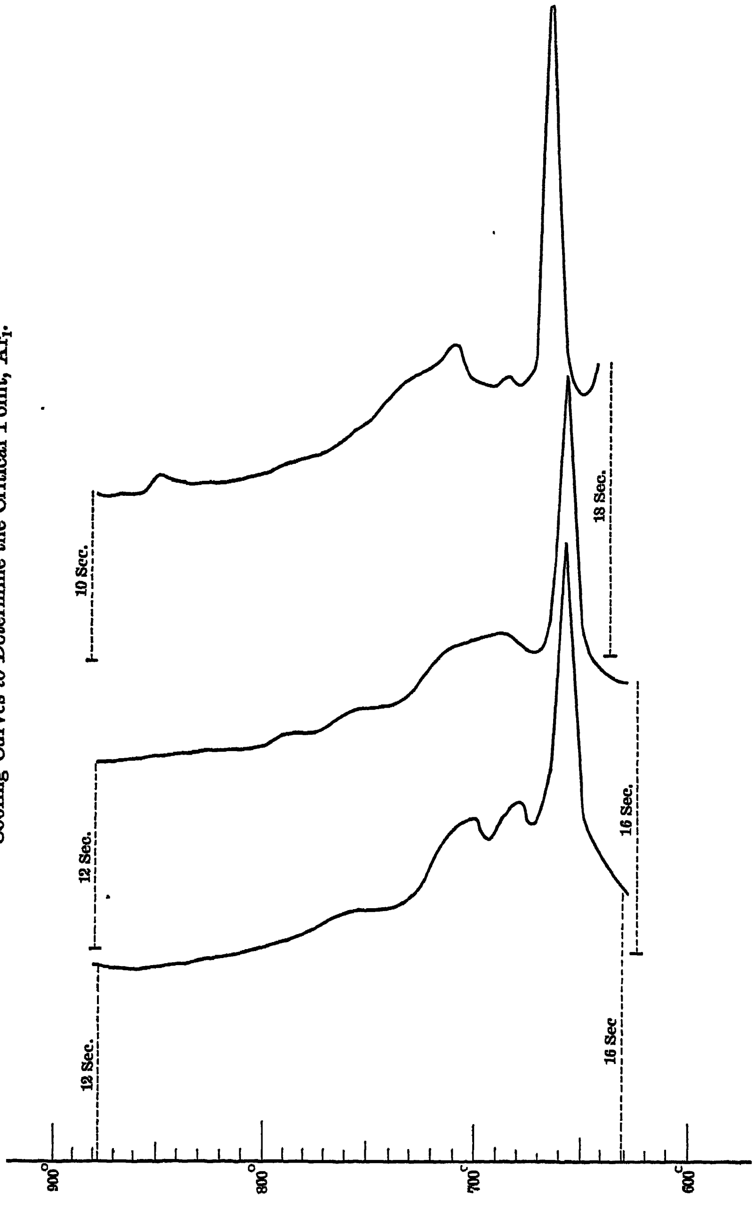
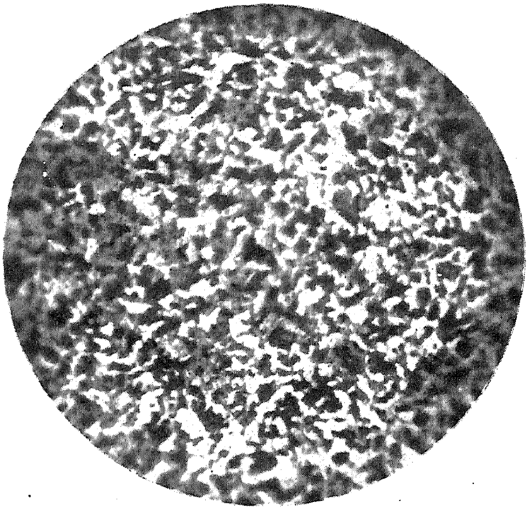


FIG. 2.
Cooling Curves to Determine the Critical Point, Ar_1.

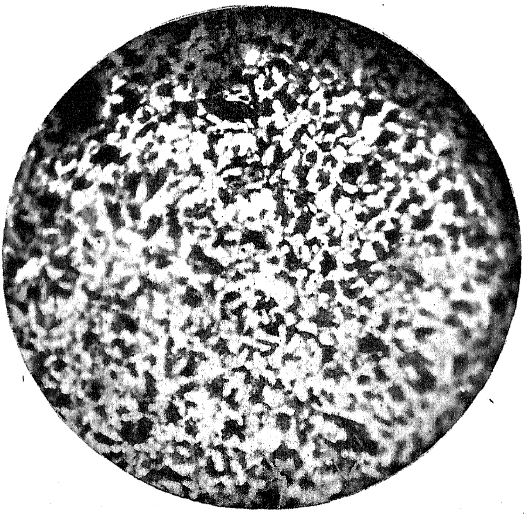
and area of the grain are taken as ordinates, and the temperatures as abscissæ.

FIG. 3.



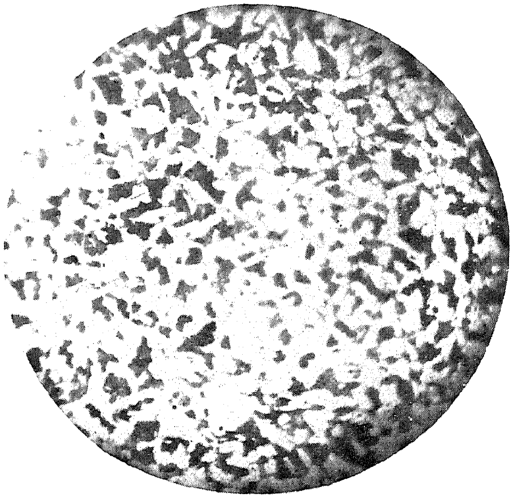
Section of Rod, before Special Heat-Treatment. 137 Diameters.

FIG. 4.



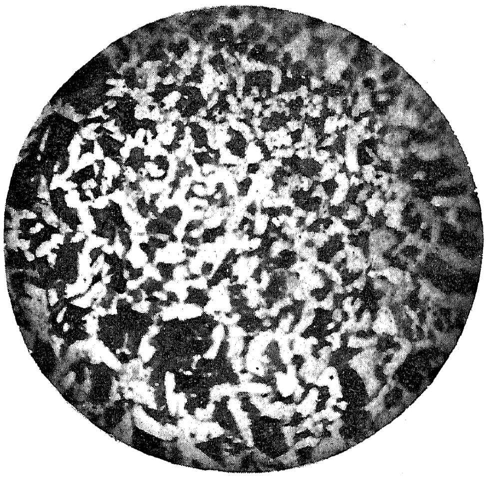
Section of Rod, before Special Heat-Treatment. 137 Diameters.

Fig. 5.



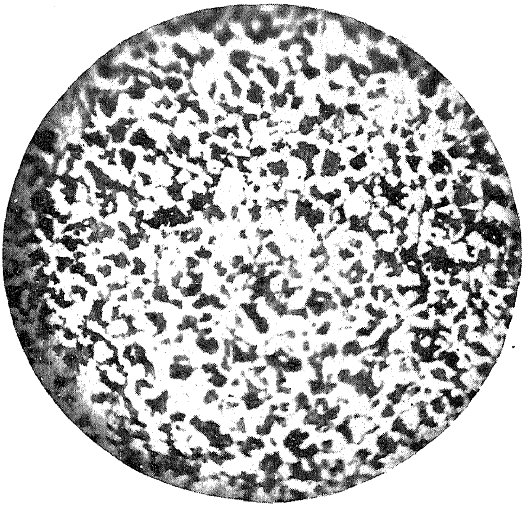
Section of Rod Heated to 500° C., and Immediately Allowed to Cool.
137 Diameters.

Fig. 6.



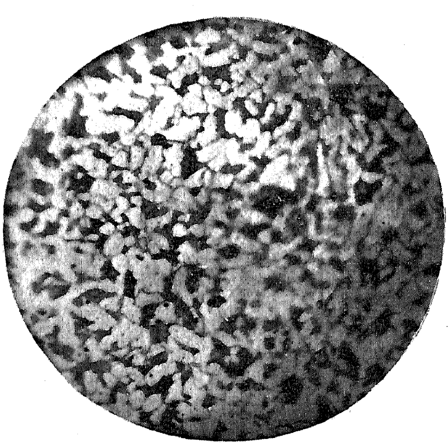
Section of Rod Heated to 600° C., and Immediately Allowed to Cool.
137 Diameters.

FIG. 7.



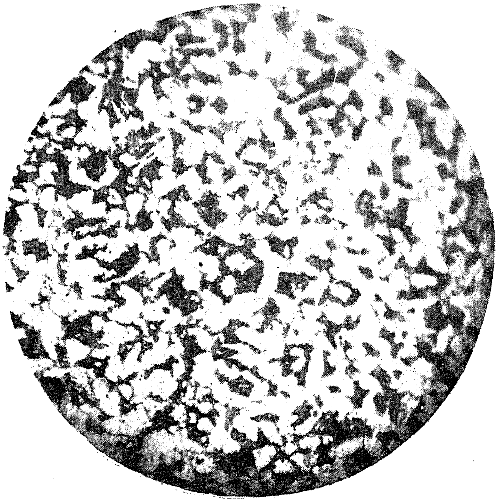
Section of Rod Heated to 646° C., and Immediately Allowed to Cool.
137 Diameters.

FIG. 8.



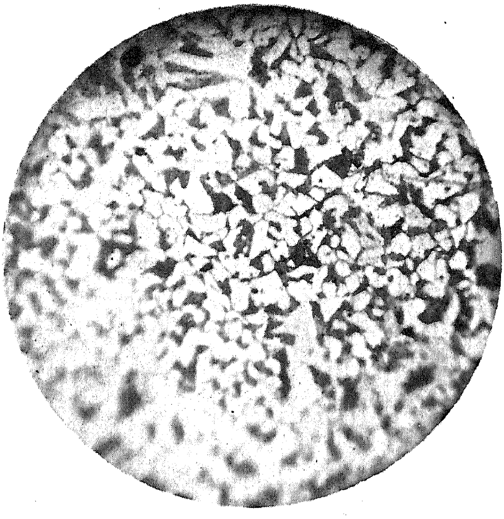
Section of Rod Heated to 646° C., and Immediately Allowed to Cool.
137 Diameters.

FIG. 9.



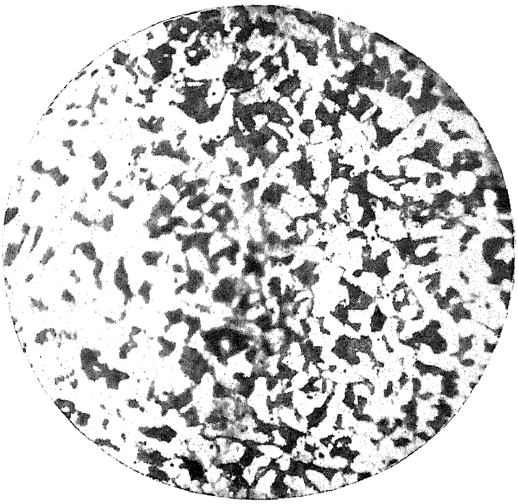
Section of Rod Heated to 600° C., and Held at that Temperature for Two Hours before Cooling. 137 Diameters.

FIG. 10.



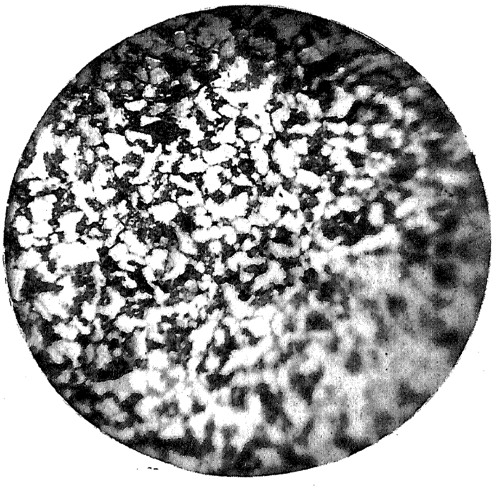
Section of Rod Heated to 654° C., and Immediately Allowed to Cool. 137 Diameters.

FIG. 11.



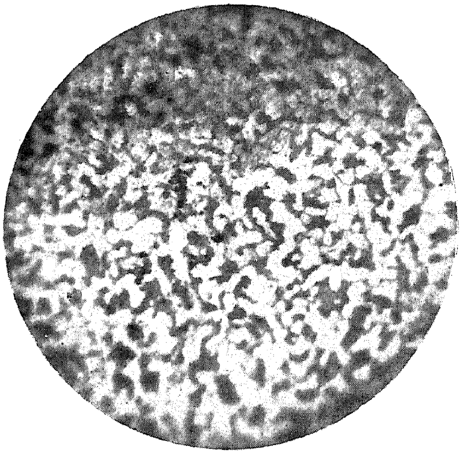
Section of Rod Heated to 680° C., and Immediately Allowed to Cool.
137 Diameters.

FIG. 12.



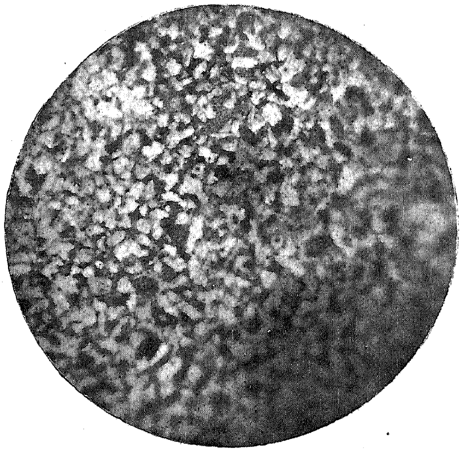
Section of Rod Heated to 725° C., and Immediately Allowed to Cool.
137 Diameters.

FIG. 13.



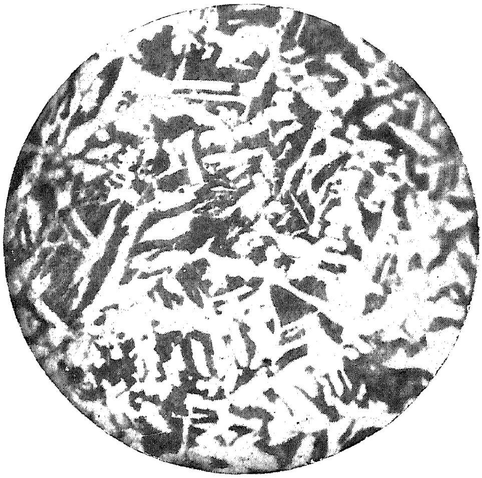
Section of Rod Heated to 800° C., and Immediately Allowed to Cool.
137 Diameters.

FIG. 14.



Section of Rod Heated to 900° C., and Immediately Allowed to Cool.
137 Diameters.

FIG. 15.

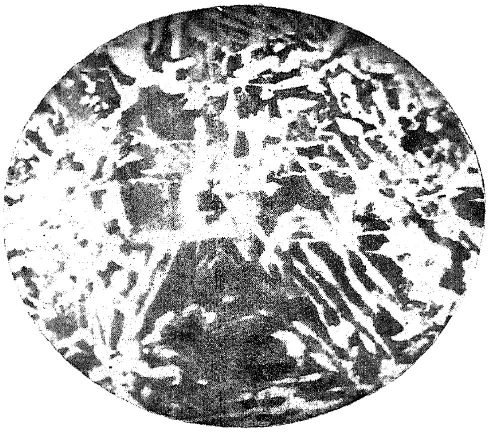


Section of Rod Heated to 900° C., and Held at that Temperature for Half an Hour before Cooling. 137 Diameters.

FIG. 16.

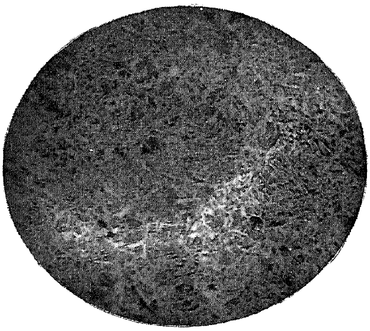
Section of Rod Heated to 900° C., and Held at that Temperature for One Hour before Cooling. 137 Diameters.

Fig. 17.



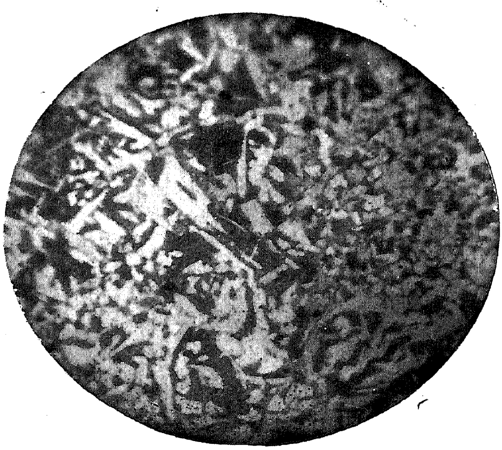
Section of Bar Heated to 900° C., and Held at that Temperature for Three Hours before Cooling. 137 Diameters.

Fig. 18.



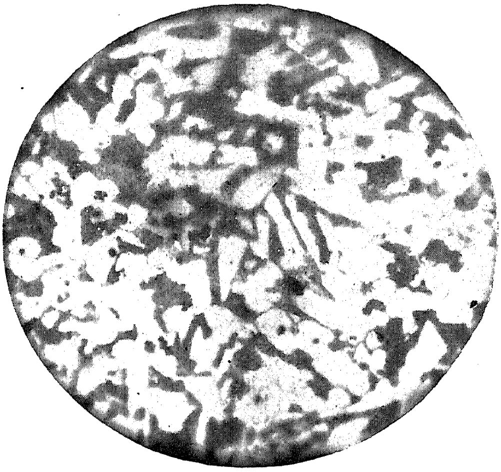
Section Fig. 17, Photographed at 35 and Engraved at 25 Diameters.

Fig. 19.



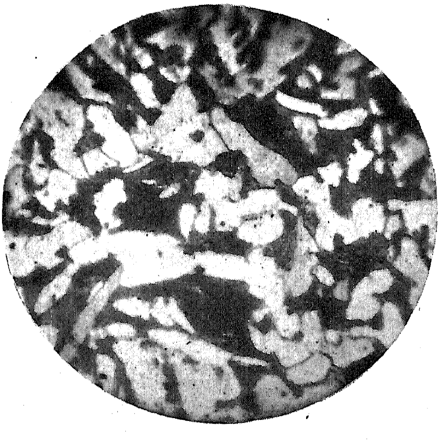
Section of Bar Heated to 1000° C., and Immediately Allowed to Cool.

FIG. 20.



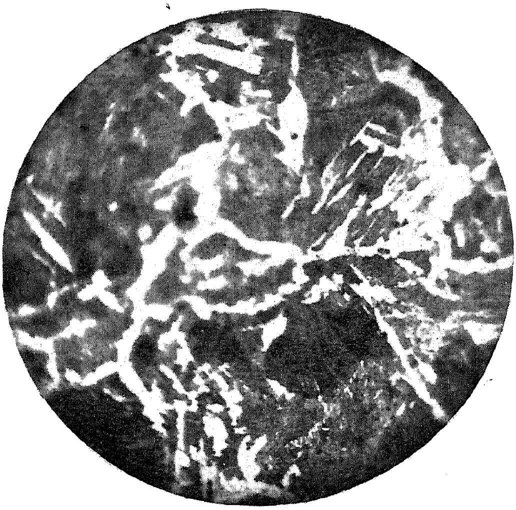
Section of Bar Heated to 1090° C., and Immediately Allowed to Cool.
137 Diameters.

FIG. 21.



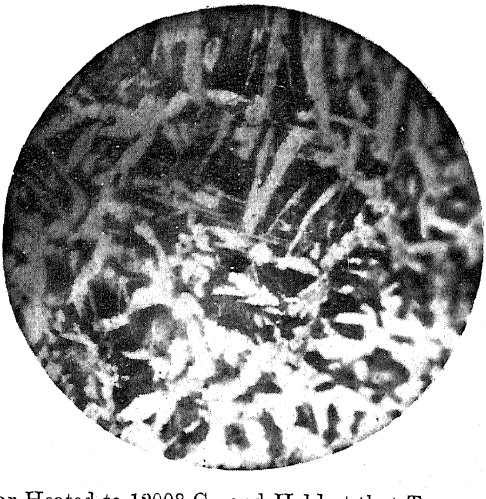
Section of Bar Heated to 1200° C., and Immediately Allowed to Cool.
137 Diameters.

FIG. 22.



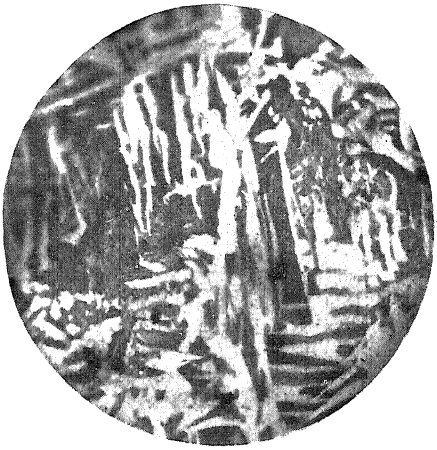
Section of Bar Heated to 1200° C., and Held at that Temperature for Half an Hour before Cooling. 137 Diameters.

FIG. 23.



Section of Bar Heated to 1200° C., and Held at that Temperature for One Hour before Cooling. 137 Diameters.

FIG. 24.



Section of Bar Heated to 1200° C., and Held at that Temperature for Three Hours before Cooling. 137 Diameters.

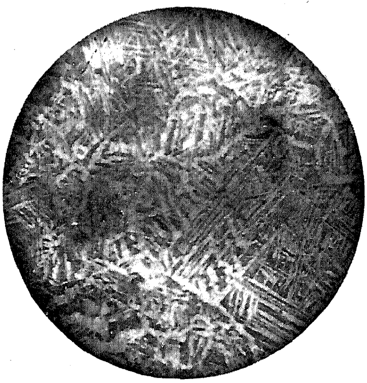
FIG. 25.

Section of Bar Heated to 1300° C., and Immediately Allowed to Cool. 137 Diameters.

FIG. 26.

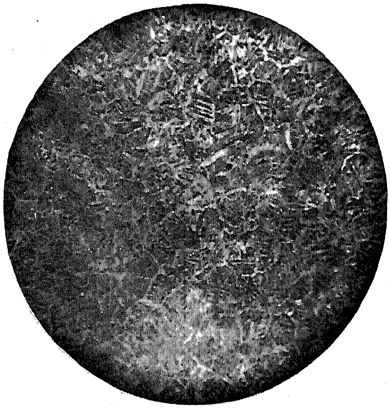
The Same as Fig. 25.

FIG. 27.



Section of Bar Shown in Figs. 25 and 26. Photographed at 35 and Engraved at 25 Diameters.

FIG. 28.



Section of Bar Shown in Figs. 25, 26 and 27. Photographed at 10 and Engraved at 8 Diameters.

Tabulated Results, Shown Graphically in Fig. 1.

Maximum Temperature. Degrees C.	Elastic Limit. Lbs. per sq in	Reduction of Area. Per cent	Tensile Strength. Lbs. per sq. in.	Elongation in 4 inches. Per cent.	Area of Grain Sq. mm.	Magnification of Photo. Diameters	Fig. No.
500	45,340	50	72,600	26	0.00024	137	5
600	42,650	48	73,230	27	0.00031	137	6
600 for ½ hr.	43,670	50	72,210	27	....	......	......
600 " 1 "	42,130	51	71,360	29	....	......	......
600 " 2 "	44,020	52	71,970	27	0.00028	137	9
646	44,430	49	72,060	26	0.00024	137	7, 8
654	44,030	52	71,610	29	0.00029	137	10
680	42,440	50	72,060	28	0.00027	137	11
687	43,000	51	72,590	27	....	......	......
700	41,470	53	69,550	23	....	......	......
725	40,820	53	71,090	23	0.00023	137	12
800	44,530	52	68,700	21	0.00020	137	13
900	46,460	54	73,430	27	0.00015	137	14
900 for ½ hr.	37,700	49	72,070	27	....	137	15
900 " 1 "	36,650	44	71,310	24	....	137	16
900 " 3 "	36,980	48	72,700	26	....	137 35	17 18
1000	42,300	47	70,920	26	0.00026	137	19
1090	33,800	44	69,210	26	0.00029	137	20
1200	45,460	45	67,340	25	0.00093	137	21
1200 for ½ hr.	35,380	42	56,890	23	....	137	22
1200 " 1 "	33,810	47	69,280	25	....	137	23
1200 " 3 "	46,010	46	68,230	23	....	137	24
1300	32,710	44	68,720	26	....	137 137 35 10	25 26 27 28
Untreated Specimens.							
....	46,680	47	72,730	23	0.00015	137	3, 4
....	44,250	52	73,090	28	....	......	......
....	44,610	52	72,420	24	....	......	......
....	45,720	50	72,480	26	....	......	......

Fig. 2 exhibits the cooling curves which determine the critical point Ar_1, shown in this case to be about 661° C.

Figs. 3 to 28, inclusive, are reproductions of the microphotographs. With three exceptions, the engravings are all on the same scale as the photographs. Figs. 18 and 27 were in photograph magnified 35 diameters, but were reduced in engraving to 25. Fig. 28 has been similarly reduced from 10 to 8 diameters.

III.—Effect of Heat-Treatment on the Microstructure.

1. *Slow Cooling Immediately from T max.*—An examination of the photographs will show that both the size and the shape

of the grain change under certain conditions. The specimens shown in Figs. 3 to 14, inclusive, have all been cooled slowly from a temperature not exceeding 900° C. The grains of ferrite in all these have the same general appearance; though of irregular shape, they are more or less equiaxed. The pearlyte is in the form described by Osmond and Werth as simple cellular. In Fig. 5 (heated to 500°) the grain is considerably larger than in the untreated specimen (Figs. 3 and 4). This is probably due to the fact that the rolling which the bar underwent in process of manufacture squeezed out the grains longitudinally, making them smaller in transverse section. (This would seem to indicate that the finishing temperature of the rolling was very low, at least below 500°; otherwise the grain would have had a chance to draw itself into a rounder shape, as appears in Fig. 6. It would be interesting in this connection to polish and examine a section cut longitudinally from the untreated bar.) The area of the grain seems to be fairly uniform until the critical point 661° is reached. Here it begins to grow steadily smaller, reaching a minimum at 900° (Fig. 14). From this point on the appearance of the grain begins to change. Passing to 1300° (Figs. 25 to 28, inclusive), we find that the form has altogether changed. For example, compare Fig. 10 with Fig. 26. In the former, the ferrite appears in distinct grains of irregular, but more or less rounded, shape, imbedded in a mass of pearlyte, giving rise to the term "simple cellular." In Fig. 26, on the other hand, a more complex condition seems to exist. The ferrite grains have grouped themselves, some into bands and some into thin lamellæ or scales, so that it is quite impossible to count them. The photographs of the specimens heated to 1000°, 1100° and 1200° (Figs. 19, 20 and 21) show the gradual growth of the ferrite grain, and the transition of the ferrite from the simple cellular to the lamellar form. The change in the ferrite grain is gradual from 900° to 1200°; but between 1200° and 1300° it seems to have lost completely its structure in separate grains, and formed itself into continuous bands or ramifications striking into, or sometimes through, the fairly well-defined grains of pearlyte. Our curve for the size of the ferrite grain must, therefore, necessarily stop at 1200°.

2. *Holding at T max. for Periods of Time.*—Figs. 14 to 18, inclusive, show what a remarkable change has taken place in the

form of the grain upon exposure to the same temperature for periods of time. At 900°, in half an hour (Fig. 15) the granular form of the ferrite has almost disappeared, though the pearlyte (at least so far as this magnification shows) has not begun to form regular grains. In an hour (Fig. 16) the ferrite has become much banded or ramified, and the lamellæ of the pearlyte have grown to a plainly visible size. At the end of three hours (Figs. 17 and 18) the ferrite has entirely lost its granular form, and the pearlyte has taken the shape of more or less regular grains surrounded by bands and pierced by striations of ferrite.

The same features are shown still more strikingly in Figs. 21 to 24, inclusive. At 1200°, after one-half hour, the pearlyte has developed into the lamellar form, and there is little left of the granular ferrite. In Fig. 24 the ferrite has become entirely banded and striated.

A comparison of Figs. 15 and 19 shows a striking similarity in microstructure between the specimen held at 900° for one-half hour and that heated to 1000° and immediately cooled. It would be interesting to determine whether this point could be carried farther; that is, whether, for example, by prolonged heating at 800°, the microstructure of a specimen could be made to resemble that of a specimen immediately cooled from 1000°.

IV.—Effect of Heat-Treatment on the Tensile Strength.

1. *Slow Cooling Immediately from T max.*—The original strength of the rolled bar does not seem to have been perceptibly affected by annealing until the critical point is reached. Here the curve drops considerably. This fall is well proven, as reference to the diagram will show that in the hollow of the curve at this point the results of all four observations are lower than either of the two next following. At about 750° the curve rises, reaching a maximum at 900°. From here it falls gradually to 1200°, and then rises again to 1300°, where our observations ended. This last point, though apparently irregular, seems to be well established, as the two results for 1300° are above both of those for 1200°.

Mr. Sauveur (in his paper of 1893) mentions a decided increase in the tensile strength of rail-steel at high temperatures.

On this point Mr. Stead says, "The structure of the large grains" (the steel had been over-heated but not burnt) "consisted of bands or strips of ferrite and pearlyte arranged more or less parallel to each other. It would appear then that such a structure, provided there is no inter-granular separation, is a remarkably tough one."

2. *Holding at T max. for Periods of Time.*—At 600°, prolonged heating lowers somewhat, but does not seem to affect substantially, the tensile strength. At 900°, the effect is not so marked as the appearance of the photographs would indicate. The tenacity of the bars held for one-half hour and for three hours (Figs. 15 and 17) is not greatly different from that of the bar (Fig. 14) which was immediately allowed to cool. The bar held for one hour (Fig. 16) was somewhat weaker. At 1200°, we find that the bar held for one-half hour (Fig. 22) is far weaker than any other specimen tested. The bars held for one hour and three hours (Figs. 23 and 24) are both stronger than the one which was immediately allowed to cool (Fig. 21).

At first it was thought that it would be possible to explain all the apparent irregularities in the curve of tensile strength by classifying the different appearances or size of the grain as representing different degrees of weakness or strength. This we are able to do in part, but not so satisfactorily as we would wish. A general relation seems to exist between the tenacity and the microstructure; namely, that the granular form is strongest with the smallest grain and weakest with the largest grain; and that the lamellar pearlyte is a very strong form of grain when well banded and pierced with ferrite. (Compare curves, Fig. 1.) This does not explain the well-marked fall in strength between 670° and 900°; nor are we able to find in the reports of any previous investigations any mention of this feature. Why the 1200° one-half hour bar (Fig. 22) is so very weak it is difficult to say. It bears a marked resemblance to the 900° one-hour bar (Fig. 16.) The figures for the tenacity of the two resemble each other in being below the curve plotted. Judging from the figures plotted the 1200° one-hour and three-hour bars should have a grain resembling the 1300° bar more closely than does the 1200° one-half hour bar. The reverse seems to be the case. To be unable to make a better comparison between the appearance of the grain and the ten-

sile strength is exceedingly discouraging. It shows that there is a new factor to be considered as affecting the microstructure, namely, the prolonged heating at a fixed temperature. Mr. Sauveur in his paper of 1893, after mentioning that there is a constant relation between the size of the grain and the properties of the metal says, "We must next endeavor to determine the extent to which the grain is affected by different finishing temperatures, and by each unit of the various impurities, carbon, silicon, sulphur, manganese, and phosphorus." The list is already a long one; and the ground which must be covered before the investigation of the effects of heat-treatment shall have been thoroughly accomplished is of vast area.

I have hesitated to draw many direct comparisons between our results and those recorded in previous investigations. In Mr. Stead's paper, as in many others, it is noticeable that the same heat-treatment has different effects upon steels of different carbon-percentages; and, indeed, the effect of the other impurities, silicon, sulphur, etc., is hardly understood at all.

In the investigation reported by Mr. Sauveur in 1893, rail-steel was used, a comparison being made between the tenacity and the size of the grain. Some of Mr. Osmond's experiments (1893) were made upon medium steel (the exact carbon-percentage is not given). Mr. Stead experimented upon steels of different carbon-percentages; but in no instance did he use steel which was within 0.14 per cent. carbon of that upon which our experiments were made. With our present lack of knowledge on the subject, it is impossible to say to what extent 0.14 per cent. of carbon would affect the results of heat-treatment.

Mr. Sauveur measured the grains in his experiments by means of a camera lucida and planimeter. Mr. Stead gives a table in which the diameter of the grains is compared with the maximum temperature of heating. His method of measuring is not mentioned.

The ground covered in this investigation was necessarily limited. Our experiments are too few and our knowledge of the subject is too limited to enable us to come to final conclusions. I therefore submit these results without further comment, hoping that at some time they may be corroborated by a more thorough investigation into the subject.

I here desire to thank Mr. Lilienberg for his kindness in furnishing us with the steel, also my fellow-student, Mr. C. H. Eckerson, who shared with me the laboratory-work upon which this paper is based.

I would acknowledge also our great indebtedness to Prof. Henry M. Howe, under whose direction and supervision the work was carried on.

Petroleum in California.

(Address delivered October, 1899, at Los Angeles, Cal., to members of the Institute, by W. L. Watts, Assistant in the Field to the California State Mining Bureau.)

THE existence of petroleum in California has been known for many years. From time immemorial the California Indians used this mineral, in the form of asphaltum, for various purposes. In the early history of the State the Catholic fathers utilized it for roofing their missions and other buildings.

It is said that in 1855 or 1856 Andreas Pico distilled petroleum on a small scale for the San Fernando Mission. He obtained his crude oil from Pico cañon, near Newhall, in Los Angeles county; and he was probably the first refiner of petroleum in this State. In 1856 a company commenced work at the La Brea ranch, in Los Angeles county, and tried to refine the crude oil. In 1857 an attempt was made to produce illuminating-oil from crude petroleum at Carpenteria, in Santa Barbara county; and there are records of similar attempts in other localities previous to 1860; but none of them were successful.

The first scientific report on petroleum in California was made by Prof. B. Silliman, who published his researches in 1865. He spoke favorably of the possibility of obtaining petroleum in remunerative quantities in this State, and gave the results of his experiments in the fractional distillation of California petroleum.

The next decade was marked by a considerable oil-excitement in California; and a great many companies were formed for the purpose of petroleum-mining and for distilling crude oil.

In most instances these companies did not meet with success; but it must be remembered that the pioneer oil-miners did not

have the drilling-machinery of the present day, and that they possessed a very limited knowledge concerning the geological conditions pertaining to the occurrence of petroleum-deposits.

The pioneer distillers appear to have expected that by the fractional distillation of California petroleum they would obtain similar products to those resulting from the fractional distillation of the petroleum found in the Eastern States; but they were disappointed. It is not surprising that, in the course of years, the smaller operators became merged in larger concerns. In 1887, when the State Mining Bureau made a reconnaissance of the petroleum-industry of California, the only companies actually engaged in petroleum-mining were: The Pacific Coast Oil Co. in Pico cañon and the Puente Oil Co. in the Puente hills, Los Angeles county; the Hardison and Stewart Oil Co., subsequently incorporated as the Union Oil Co., of Ventura county; and McPherson & Co., operating in Moody Gulch, in Santa Clara county.

The first refinery that could be considered a commercial success was that of the California Star Oil Co., situated near Newhall, in Los Angeles county, and managed by T. H. Scott. Subsequently, refineries were erected at Alameda by the Pacific Coast Oil Co., and at Santa Paula by the Union Oil Co. At the present day there are refineries at Los Angeles, Chino, Ventura and Alameda, also at Oleum in Contra Costa county, to which place the refinery of the Union Oil Co. was removed.

During the last decade there has been a steady increase in the amount of petroleum produced in California and in the amount of oil-territory developed. In 1889 the output of petroleum for the State was 303,220 barrels; in 1898 it was 2,249,088 barrels, an increase of more than sevenfold.

The California petroleum is found in formations which range from the Lower Cretaceous to the Quaternary, the greater portion being in the Eocene and the Neocene formations. In this State it is imperative that oil-mining operations should be governed by a careful study of the structural geology of the locality in which they are conducted; for wherever petroleum has been found in California, geological disturbance has complicated the stratigraphic conditions.

To those who explore the hills and mountains of the Coast range there are few things more interesting than the curiously folded condition of the rocky strata. In California the student

of structural geology has not to search very far before he finds natural illustrations of the types of folds he has seen in his text-books. In some parts of the world such folds are many miles in breadth; but in the Coast range the conspicuous folds are generally narrow ones. The small and conspicuous folds usually constitute portions of larger folds, which, although they are more important than the small folds in the formation of hills and mountains, are not so easily detected, unless a large area is carefully mapped out and studied. The small folds are, however, of great importance in determining the course and the width of "oil-lines."

It is reasonable to suppose that the compressed folds do not extend to a great depth in a uniform curve, but that the rock-masses have been readjusted by reciprocal movement. Wherever there has been so much geological disturbance as is the case in the Coast range, it is evident that structural conditions must be modified, not only by faults and fissures, but also by the thinning or thickening of the softer strata by reason of the compression to which they have been subjected. When the outcrop of the oil-yielding stratum can be found, it constitutes a most important guide to the prospector. A careful observation of it shows the horizontal direction in which the oil-sand extends and the angle at which it is inclined. From the latter factor the depth at which the oil-sand can be struck by drilling at any given distance from the outcrop can be calculated. But it frequently happens that the oil-yielding stratum does not crop out at the surface of the ground. In such cases, its dip and strike must be inferred from any of the rocks enclosing it which may be exposed, provided, always, that the oil-sand and the enclosing rocks are conformable. In California it frequently happens that, within a limited area, the exposed strata show a great diversity of dip, and the best guide as to the prevailing strike of the formation is the strike of the axis of the fold into which the strata have been thrown.

When the exposed rocks are situated near the axis of a fold, or when the fold of which they form a part is overturned, they are by no means an infallible guide as to the prevailing angle of the dip. In locating an oil-well, the character of the fold affecting the rocks about to be prospected should be taken into account. There are conditions of the rocky strata, besides those of folding, which may determine the existence and the

course of oil-lines, and the most important of these are faults. The class of faults most likely to result in the formation of oil-lines are those which have been caused by fractures extending in the direction of the strike of the formation, and which have allowed blocks of the earth's crust to slip past one another so that they are arranged in the form of steps. In areas of great compression, like that of the Coast range, it might be supposed that all the faults would be thrust-faults, but in many instances the fracture which occasioned the fault is nearly vertical to the plane of the horizon—in which event it is frequently the case that the force of gravity controls the thrust.

The California oil-fields which have as yet been developed are situated in Los Angeles, Ventura, Santa Barbara, Kern, Kings and Fresno counties.

Oil-yielding formations have been traced throughout the Coast range, almost from San Diego to Del Norte counties. North of San Francisco no oil-fields have as yet been developed, but prospect-wells are being drilled at several places.

The most remarkable features in the recent history of the petroleum industry in California have been the development of the Los Angeles oil-field, the Summerland oil-field in Santa Barbara, and the oil-field of Coalinga in Fresno county. The Summerland oil-field has been described, and the history of its development has been recorded in the reports and bulletins of the California State Mining Bureau, and in the work recently published by the Miners' Association on the *Mines and Minerals of California*. The Coalinga oil-field is the most important yet developed in the border of the Central Valley of California. It is remarkable both for the amount and the quality of the oil which it has produced. Very productive oil-fields have also been developed at the Kern river and at McKittrick in Kern county.

In the Los Angeles oil-field fully 1100 wells have been drilled within an area of about 2¼ miles in length and less than a quarter of a mile in width. Moreover, a western extension of that oil-field is rapidly being developed about a mile to the westward of what has heretofore been known as the Los Angeles oil-field. The first portion of the oil-field developed was at Second street park; and the discovery that oil existed there in valuable quantities was due to the enterprise of Messrs. Doheny

and Connon, who commenced operations by sinking a prospect-shaft 155 feet deep, at the corner of Patton and State streets. The way in which a forest of derricks grew up, as if by magic, and a district of quiet residences was transformed into a mining center, is matter of history.

The Los Angeles oil-field, developed as it was in the midst of a city, is in itself a remarkable incident in the history of oil-mining. Furthermore, it gave an impetus to the petroleum-industry in California, which within three years caused this industry to rise from a position of comparative insignificance to one of great importance.

The formation penetrated by the Los Angeles oil-wells is a shale containing strata of oil-yielding sandstone. This formation is of Neocene age, that is, of the age between the Miocene and Pliocene. An examination of the rocks exposed at the surface showed that the direction in which the strata dipped was S. 10° W., and that in most places the angle of inclination was less than 45°. The rocks exposed at what is now the eastern end of the oil-field, near the corner of Beaudry and Bellevue avenues, showed a sudden rise in the angle of the dip, together with other evidence of geological disturbance.

This was the first intimation that trouble was to be expected in that direction. Investigation further to the eastward, however, showed that the area of geological disturbance noted at the corner of Beaudry and Bellevue avenues could not be of great width. Events proved that these surface-indications were true prophets; for a line of geographical disturbance was encountered at the eastern extremity of the old field, and a new field was discovered a few blocks further to the eastward. The direction in which the oil-field was extending to the westward showed that it would eventually reach the corner of Quebec street and Ocean View avenue, near which point the rock-exposures indicated another line of geological disturbance. This foreboded more trouble for the drillers, and the indications were not misleading.

The direction in which the western extremity of the oil-line had been developed caused grave apprehensions lest it might invade the more expensive residence-portion of the city and mar the beauties of Westlake park. Many persons held to the opinion that the strike of the oil-sand, *i.e.*, the horizontal direction in which it extended, was south of west instead of north of

west. A careful investigation of the exposed rocks, and calculations from the different depths at which the oil-sand had been struck in different parts of the oil-field, showed that the strike of the oil-sand was a little north of west, and, consequently, that the oil-line, which had been developed, if it extended to the westward, would not strike Westlake park, but would pass a little south of the Baptist College. An examination of the rocks exposed in a creek flowing past the Baptist College and the Maltman wells led to the conclusion that a sequence of formations was exposed there which corresponded to the formations penetrated by the wells in Second Street park. The deductions mentioned were published in a bulletin issued by the California State Mining Bureau in 1896; and subsequent developments have demonstrated their accuracy. This shows that systematic investigations do throw light on the subject of oil-mining, even ahead of the drill.

As is well known, the petroleum found in the eastern States is composed principally of hydrocarbons of the paraffin series. Investigations hitherto made on the petroleum found in California have shown that they are composed principally of hydrocarbons containing a greater percentage of carbon than do the corresponding members of the paraffin series. It is this excess of carbon that causes the difficulties experienced in manufacturing from the California petroleum illuminating-oils which can successfully compete with illuminating-oil manufactured from Eastern petroleum.

Although only a small portion of the California petroleum is available for the manufacturing of illuminating-oil, it can be resolved into other valuable commodities. It yields naphthas, gas-distillate, lubricating-oil and asphaltum. The greatest value of California petroleum is that it furnishes an excellent fuel. Repeated tests have shown that, for fuel-purposes, from two and a half to four barrels of crude petroleum may be taken as the equivalent of one ton of good coal, the ratio of value differing according to the conditions under which the petroleum is burned.

The use of petroleum as fuel in this State certainly dates as far back as 1878. Although its superiority to solid fuel has been demonstrated for more than twenty years, it has only recently commenced to crowd out the black diamond from the railroad and the workshop. When it is considered that many

millions of dollars are annually expended by California for imported coal, and that the substitution of petroleum for coal would result in the expending of these millions on a home-product, the importance of the petroleum-industry to this State can be appreciated.

The Manganese-Deposits of Bahia and Minas, Brazil.

BY PROF. JOHN C. BRANNER, STANFORD UNIVERSITY, CALIFORNIA.

(California Meeting, September, 1899.)

WITHIN a couple of years I have received many inquiries in regard to the manganese-mines of Brazil. These inquiries were doubtless directed to me because I had lived and traveled in Brazil for more than eight years, and was therefore supposed to be pretty well acquainted with its geology and mineral resources. Somewhat to my chagrin, I not only knew nothing of manganese-mines in that country, but I had never before heard of the mineral having been found here in quantity, and I did not even know in what State the mines were located.

The present summer found me in Brazil again, trying to finish up some of my early geological investigations along the northeast coast, and I have used the occasion to find out something about the manganese-deposits.

Very little is known of these mines, even in Brazil. While at Pernambuco I was told that they were in the distant interior of the State of Bahia. In August I reached Bahia, and there I found out, concerning the mines and their geology, enough to be worth telling for the benefit of those interested in the mining or using of this mineral.

Thus far, all the manganese-ore shipped from this State has come from two mines, the principal one of which is known as the Pedras Pretas mine. This was the first mine opened, is the best developed, and was the original discovery; the second one is on an [illegible] tract, and the general geology and natural conditions are about the same in both.

The Pedras Pretas mine is on the Nazareth-Amargosa railway, twenty-six kilometers west of the town of Nazareth, which is on tide-water, at the head of navigation, and is reached from the city of Bahia by a small side-wheel steamer that runs across the bay of Bahia and up the Rio Jaguaripe

to that place two or three times a week. The trip usually takes about six hours. The Amargosa railway, running out of Nazareth, passes within half a mile of the mines.

To my regret, though I started to visit these mines, I did not get further than Nazareth. There I met the gentlemen in charge of them; and, owing to necessary connections to be made with a long-period steamer down the coast, I was compelled to gather what information I could, and to turn back. What I have to say here, therefore, regarding the mines themselves, was obtained in conversation with Mr. Charles Nack, the chief owner of the Pedras Pretas property, and from the engineer's maps, sections, etc. For what I say of the general geology, I alone am responsible.

The geology of the deposit is of special interest; for, so far as I now recall, manganese has not before been found in such rocks, though there was, of course, no reason for supposing it might not be expected in them. These rocks are *decomposed crystalline schists*. Mr. Nack speaks of them as decomposed gneiss, and the rocks do have a certain resemblance to gneiss. Indeed, in many places through this part of the country, it is often difficult to say just where the gneisses end and the crystalline schists begin. The schist-series is exposed at the city of Bahia, and is common in all the eastern States of Brazil, along the inland margin of the Cretaceous belt that follows the coast from Rio Grande do Nortê down nearly to Rio de Janeiro. These schists, and also the gneisses and granites that often accompany them, are in some places exposed as hard rocks, while in others they are profoundly decomposed. The railways in the States of Pernambuco, Parahyba do Norte and Alagôas have many deep cuts through granites, gneisses and crystalline schists completely decomposed in place. Some of these cuts are twenty meters and more in depth, with not a rock in them hard enough to require blasting.*

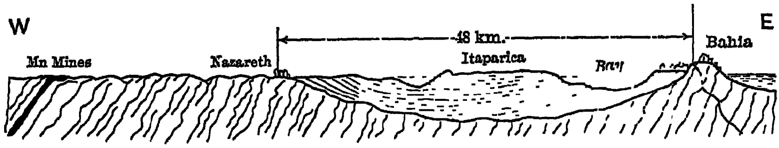
It is a peculiarity of these rocks, however, that while they are often decomposed to a depth of a hundred meters or more, there is no telling where one will come abruptly to the end of this decomposition. Here and there, throughout these regions of rock-decay, are bare peaks of solid granite, gneiss or schist,

* See "Decomposition of Rocks in Brazil," by J. C. Branner, *Bull. Geol. Soc. Amer.*, vii., 255–314.

hundreds of meters in height. In the [illegible] one may often see half of the cut in solid rock and the other half in clays that have been excavated with pick and shovel alone.

To come to the geology of the particular region with which we are here concerned:—the city of Bahia stands upon crystalline schists cut by eruptive dikes. Immediately west of the city is a Cretaceous basin that rests unconformably upon these crystalline rocks, and extends westward to within a couple of kilometers of the town of Nazareth—a distance, as the parrot flies, of about forty-eight kilometers. At Nazareth the schists are so decomposed that solid rocks in place are to be seen only in the stream-beds, and here and there in the hills. It is in these decomposed rocks that the manganese is found at the Pedras Pretas mine, lying, according to Mr. Nack, twenty-six kilometers further west. Fig. 1 is an ideal section, from Bahia westward.

FIG. 1.

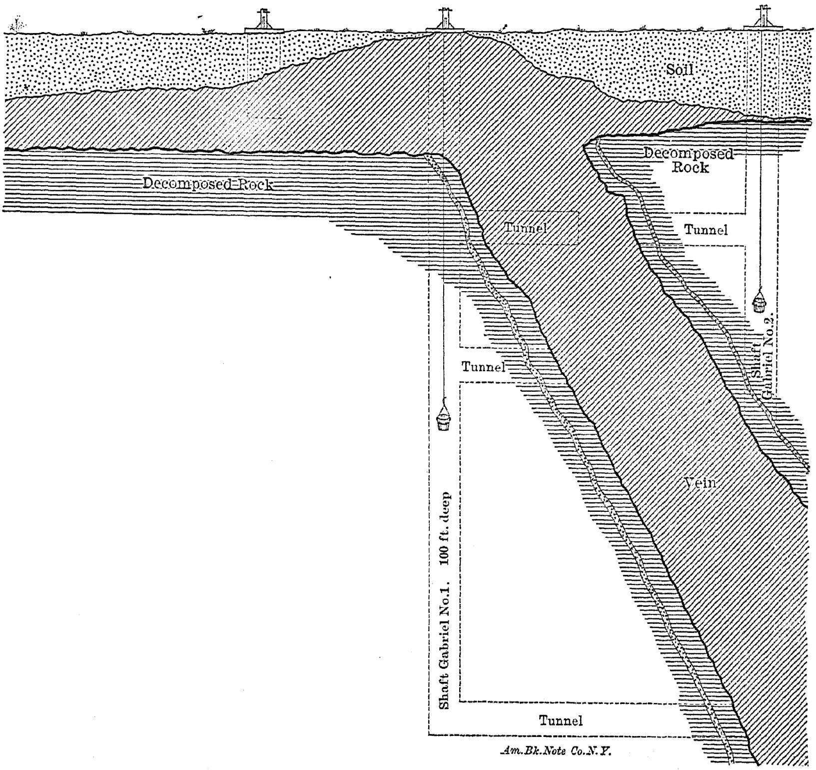


Ideal Section from Bahia to the Pedras Pretas Manganese-Mines. The underlying rocks are crystalline schists, with eruptive dikes, and possibly some granites and gneisses. The beds resting upon these are Cretaceous sediments.

Nothing definite is known with regard to the geologic age of these rocks; and the only opinion safe to venture is that they are very old. In the State of Sergipe, next north of Bahia, a series of rocks, *believed* to be Paleozoic, rests unconformably upon gneisses and schists. This would make the latter older than the Carboniferous at least. Some years ago Professor O. A. Derby, if I remember correctly (for this is written away from my Brazilian library), published in the *American Journal of Science* an article showing that some of these crystalline rocks were to be correlated with the Laurentian rocks of Canada, basing this view upon the discovery of what was thought by Sir William Dawson to be *Eozoon canadense.** Leaving aside the question about *Eozoon*, I can only say that, so far as general resemblance over large rock-areas can be trusted for such correlation, I am altogether disposed to agree with Professor

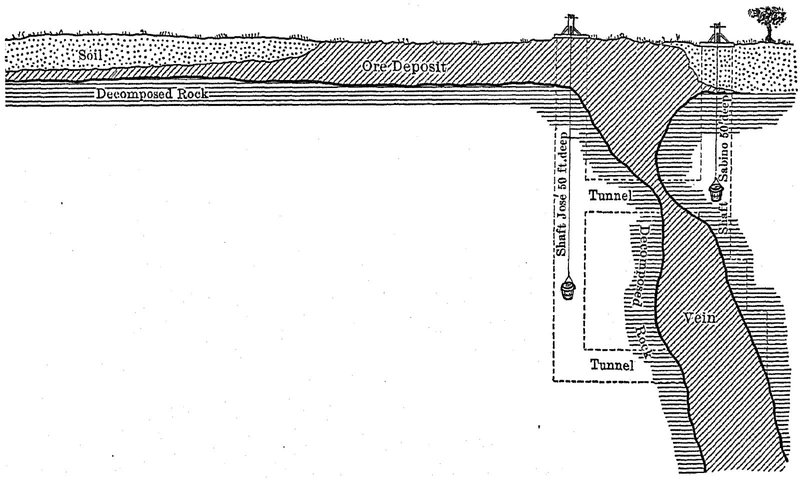
* *Am. Jour. Sci.*, cxix., 326 (1880).

FIG. 2.



Section through the Pedras Pretas Manganese-Mines, Bahia, Brazil.
Scale, 1 inch = 25 feet.

FIG. 3.



Section through the Ore-Body and Workings of the Pedras Pretas Mine, Bahia, Brazil.
Scale, 1 inch = 25 feet, nearly.

Derby. I dare say Professor Van Hise would be struck by the strong resemblance between these Brazilian schists and those of the Algonkian of Wisconsin, Minnesota, etc. And it is interesting to remember that these Brazilian manganese-beds are thus in rocks of approximately the same geologic age, and certainly of the same general appearance and characteristics, as the great iron-bearing series of the northwestern United States.

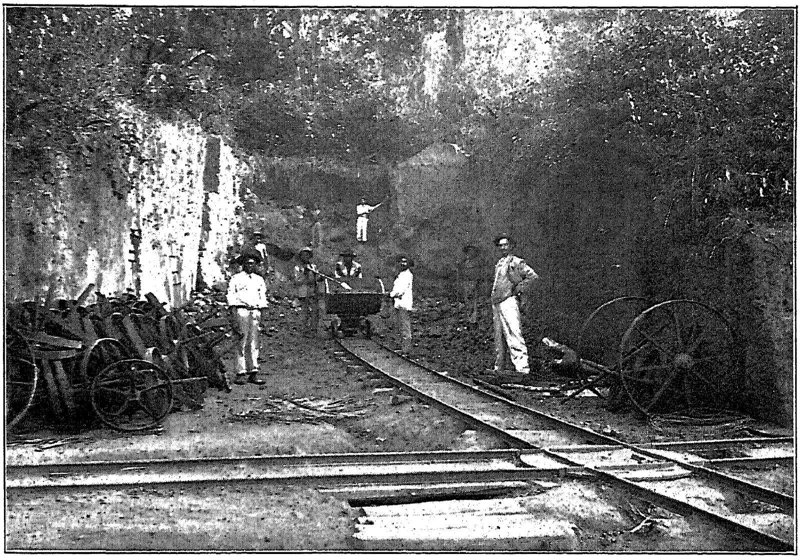
The country in which the manganese-mines are located is the comparatively low, hilly coastal region of eastern Brazil. The elevation of the water-shed at the mines is 198 meters above tide-level, and 70 meters above the track of the Amargosa railway, near by. This belt of country is covered by dense forests. The property of the Pedras Pretas Company consists of 295 acres of land, lying between Nago and Mutum creeks, and sloping northward towards the former stream. The other mine now being opened lies just south of the Pedras Pretas property, on the south-facing slope of the same hill.

The ore is psilomelane, and, in so far as one can judge by looking at it, fine ore it is. Hundreds of tons of it were piled on the wharf at Nazareth when I was there, on the 24th and 25th of August, 1899. Compared with the Arkansas and Georgia ores, it appeared to me to be unusually clean, though all of it is somewhat stained with red clay. Some of the lumps are botryoidal in form, but most of them are angular, and many are more than two feet in diameter. I am told that at the mines it is no uncommon thing to find lumps that weigh one and a half tons. The smallest pieces on the ore-piles I saw are larger than one's fist; and these pieces make but a small part of the ore on the heaps.

The Pedras Pretas mine is in soft earth, save where large masses of solid ore have been drifted into. Most of the ore thus far shipped has come from the great horizontal sheet that spreads out, almost or quite on the surface of the ground.

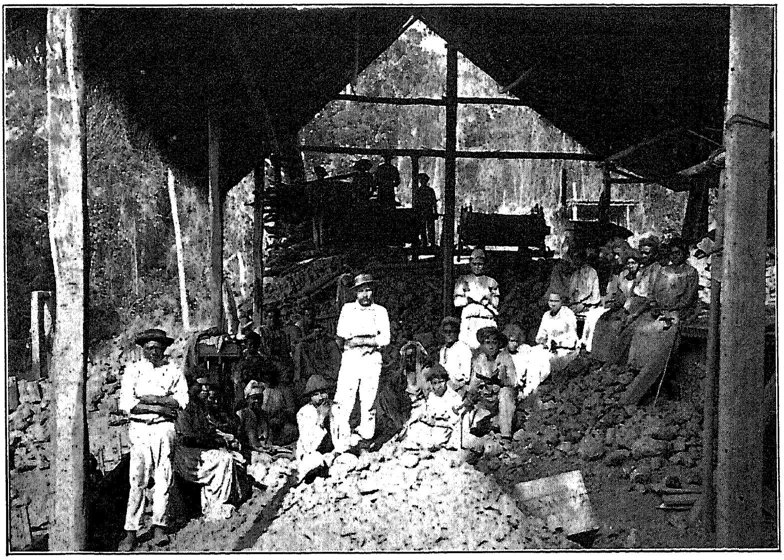
From the engineer's maps and sections (Figs. 2 and 3) one can see just how much is fact, and how much theory, with regard to the size and shape of the ore-body. It seems evident that there is a sheet, bed, or vein, as one may choose to call it, of ore, standing at an angle of sixty degrees, and varying in thickness from a few decimeters to ten meters. The great surface-deposits I take to be the accumulation from the breaking-up

FIG. 4.



Open Cut in Surface Clay (Decomposed Rock), Pedras Pretas Manganese-Mine, Bahia, Brazil.

FIG. 5.



Method of Cleaning Manganese-Ore at the Pedras Pretas Mines. The ore is dried by fire upon a grate of railway-iron, shown on the right; the clay is then knocked off by women, and the ore is dropped into the ore-shoots on the left.

and weathering-out of the bed, and the removal of the clays about it*—just as the Arkansas ores come from the decomposition of limestones. Most of the ore thus far shipped has come from these surface-accumulations. Fig. 4, from a photograph said to have been taken in June last, shows one of the open cuts in this surface-clay.

Anyone acquainted with the manganese-mines of Arkansas, Georgia and Virginia, will be struck by the general similarity of the conditions under which the ores occur in Brazil. The only remarkable difference is in the age of the rocks—the Brazilian ones being probably much older.

Fig. 5 shows a method of ore-cleaning that may be useful elsewhere. On the right is a pit covered with railway-iron, the rails lying close against each other, and sloping gently towards the shed. A fire is kept beneath these rails, and all the ore that comes from the pits covered with clay is dumped upon these hot bars, and left there until the clay dries. It is then raked off, and the clay is removed by rapping the ore-lumps with hammers. The ore is then dropped on the chutes shown on the left. This ore-cleaning is all done by women. When the ore comes from the mines clean, the cars are dumped immediately into the chutes.

The company owns a tramway over which its ore is hauled to the Nazareth-Amargosa railway, by which it is taken to the wharf at Nazareth. At this place it is loaded on small sailing-vessels and sent to Itaparíca, a small town on the Bay of Bahia, where it is put on board sailing-vessels for Europe or the United States.

The government-charges here are quite reasonable—a little more than one milreis a ton on the exported ore. At the present rate of exchange, this is about fifteen cents of our American money. I am told that sailing-vessels charge ten shillings a ton to carry the ore from Bahia to Philadelphia.

As reported to me by the mine-owners, the total cost (to them) of this manganese, laid down in Philadelphia, is four dollars and ninety-five cents a ton. This includes the cost of mine management. From my own knowledge of this country, and

* I have often found these crystalline schists to have a pretty uniform dip and strike over large areas through eastern Brazil. In the interior of the State of Pernambuco I found that this uniformity was due to repeated parallel faults.

of the price and character of labor, I am disposed to think this a thoroughly conservative estimate.

The proximity of the fine sea-port and large city of Bahia makes it possible for those living at these mines to have many of the luxuries of life, while the many steamer-lines running to this port from Europe (and one from the United States) keep them from feeling that they are very far from the rest of the world. On the whole, the mines are more favorably located than any others with which I am acquainted in Brazil. Labor is very cheap, and, if properly treated, is fairly good. There are a large saw-mill and many shops at the town of Nazareth.

As for the prospects of finding other good manganese-deposits, it would be a mere waste of words to speak, save in the most general terms. The geology of the country is but imperfectly known at the best, and nothing at all is known of the precise distribution of the series of rocks in which these particular deposits are found. The federal government has no lands of its own. When the republic was established, it was provided in the Constitution that all federal lands should be turned over to the States in which the lands lay. There is, therefore, no incentive for the federal government to maintain a geological survey, since such a survey would be for the sole direct benefit of the individual States. The States themselves, with the exceptions of São Paulo and Minas Geraes, have never undertaken such work; and the Minas Geraes survey has already been stopped, before any geological work proper had been undertaken. I regret to say that there seems but little likelihood of the States undertaking surveys. If any one wants to know where the crystalline schists occur in the great State of Bahia, in order to know where to seek manganese, he need not search the State reports for such information; he can either gather the information directly in the field, or he can leave the matter alone. But such preliminary field-work is quite beyond the powers of private organizations. So he leaves it alone; and whatever new discoveries are made must be made by some happy chance.

Postscript.

After the above was written (at Bahia, in August, 1899), I went to Rio de Janeiro, with the expectation of visiting the

manganese-mines near Ouro Preto, in the State of Minas Geraes. I found, however, that a competent English mining engineer had already spent some time studying them, and that his results were shortly to be published in England; and I therefore abandoned my plans. The Minas Geraes manganese-deposits are near the Miguel Burnier Station on the Ouro Preto branch of the Central railway (496 kilometers north of Rio), and at Queluz on the main line (463 kilometers from Rio). From what Professor Derby and others who have seen the mines tell me, they are all open cuts in rocks decomposed in place. With the general geology of the region in which these mines are located I am already acquainted. It is very much like that of the Bahia manganese-mines.

Dr. Antonio Olyntho dos Santos Pires, Professor in the Escola de Minas at Ouro Preto, and one of the leading mining engineers of Brazil, has kindly furnished me the following information regarding the Minas manganese-deposits. His letter is dated October 22, 1899.

"About five years ago the manganese-mines of the State of Minas began to attract attention, though in many places these deposits were already well known. In the zone between Miguel Burnier and Itabira, on the Central do Brazil railway, two iron-furnaces had been started alongside of magnificent iron-deposits; but the difficulty of getting charcoal for fuel caused the directors of one of these furnaces to turn their attention to the manganese, and to attempt its exportation. The result of this attempt was favorable; and from this began the regular mining and shipping of this mineral.

"At present there are three companies engaged in this work, besides the small organizations that are formed and disappear from time to time. These companies operate in the zone between Lafayette and Burnier stations, along the branch railway running from Burnier to Ouro Preto, and lately in the vicinity of the last-named city. It is only within the last two years that these mining operations have become systematized. Of the geology of these deposits no careful studies have been made. The region is very mountainous, and has been much disturbed, and only a thorough and careful examination can warrant hypothèses—which, thus far, no one has ventured to formulate. The order of the beds, as shown in most of the cuts along the Ouro Preto branch of the railway, is about as follows:

1. Limestone.
2. Ferruginous quartzite or itabirite.
3. Clays.
4. Compact itabirite.
5. Manganese.
6. *Jacutinga*, or friable itabirite.
7. Clays.
8. Stratified crystalline rocks, with limonite and impure manganese oxides.
9. Clay-shales.
10. *Canga*, or ferruginous conglomerate.

"The kinds of manganese most frequently found are *manganite* (Mn_2O_3, H_2O) and *pyrolusite* (MnO_2), and less frequently the other oxides. The itabirite with which the manganese is generally interbedded is composed of hematite and layers of quartz. It is sometimes so compact that it is called ironstone; and again it is friable, when it is known as *jacutinga.*

"I give herewith analyses showing the percentage of metallic manganese, and of the principal impurities contained in the ore. These analyses are copied from the register of analyses of the School of Mines, where we examine all the ores presented.

"The exportation of manganese from the State of Minas began (by way of the port of Rio de Janeiro), upon a very small scale, in 1894. In subsequent years it was as follows:

EXPORTS OF MANGANESE FROM MINAS
(via Rio de Janeiro).

	Metric Tons.*
1895,	6,765
1896,	13,020
1897,	17,967
1898,	29,630
1899 (to Sept.),	60,107

"This exportation was through the Miguel Burnier station, at kilometer 498 on the Central do Brazil railway. There has also been some manganese exported from Lafayette station (kilometer 462) and from Ouro Preto (kilometer 540); but only during the present year has it become regular. To the figures given above there should therefore be added at least 15 or 20 per cent., to show the total exportation of manganese from the State of Minas.

"These figures show that mining operations are increasing; and the work planned and development now under way lead to the belief that the output for next year will be much larger than ever. Moreover, other districts, such as that of Sabará and Bello Horizonte, along the line of the Central railway, are proving to contain deposits of importance which must certainly be developed shortly."

The following are the analyses of manganese-ore, made at the School of Mines at Ouro Preto, and kindly furnished by Dr. Antonio Olyntho.

I.

Sample from Kilometer 499, Central do Brazil Railway.

	Per cent.
Loss on ignition,	15.200
Insoluble in HCl,	1.560
Sesquioxide of iron, and alumina,	4.600
Oxide of manganese,	76.200
Baryta,	1.840
Phosphoric acid,	0.019
Total,	99.419
Metallic manganese,	54.96

* The metric ton is 2204 lbs. avoirdupois.

II.

Sample from Kilometer 500, *Central do Brazil Railway.*

	Per cent.
Loss on ignition,	14.750
Insoluble in HCl,	0.700
Sesquioxide of iron,	4.000
Alumina,	2.000
Lime and magnesia,	0.000
Oxide of manganese,	75.600
Phosphoric acid,	0.051
Baryta,	2.300
Total,	99.401
Metallic manganese,	50.46

III.

Sample from Kilometer 503, *Central do Brazil Railway.*

	Per cent.
Loss on ignition,	13.500
Insoluble in HCl,	1.000
Sesquioxide of iron and manganese,	5.700
Oxide of manganese,	70.000
Phosphoric acid,	0.032
Baryta,	8.800
Lime and magnesia,	trace
Total,	99.032
Metallic manganese,	50.44

IV.

Sample from Itabira, Kilometer 524, *Central do Brazil Railway.*

	Per cent.
Hygroscopic moisture,	1.15
Insoluble in HCl,	13.84
Metallic manganese,	31.75

V.

Sample from Vigia, Kilometer 500, *between Burnier and Itabira Stations.*

	Per cent.
Insoluble in HCl,	0.65
Metallic manganese,	55.40

VI.

Samples from Queluz, Lafayette Station, Kilometer 463, *Central do Brazil Railway.*

	I. Per cent.	II. Per cent.
Loss on ignition,	14.0	18.7
Insoluble in HCl,	52.0	5.0
Metallic manganese,	29.8	36.7

VII.

Samples from Rodrigo Silva, Kilometer 521, Central do Brazil Railway.

	I. Per cent.	II. Per cent.	III. Per cent.
Insoluble in HCl,	3.5	0.3	0.40
Metallic manganese,	60.1	62.0	60.90
Phosphorus,	0.154		

VIII.

Sample from Rodrigo Silva, another exposure.

	Per cent.
Insoluble in HCl,	1.65
Oxide of manganese,	69.00
Phosphoric acid,	0.160
Corresponding to	
Metallic manganese,	49.70
Phosphorus,	0.07

IX.

Sample from Hargreaves, Kilometer 515, Central do Brazil Railway.

	Per cent.
Insoluble in HCl,	1.8
Oxide of manganese,	71.5
Oxide of iron and alumina,	14.6
Corresponding to	
Metallic manganese,	51.4

X.

Samples from H[illegible]. Capão Deposit.

	I. Per cent.	II. Per cent.
Insoluble in HCl,	0 4	0.3
Alumina,	12.5	
Metallic manganese,	48.96	57.4
Phosphoric acid,	0.096	

XI.

Sample from Saramenha, Kilometer 540.

	I. Per cent.
Loss on ignition,	18.50
Insoluble in HCl,	0.80
Alumina,	0.90
Sesquioxide of iron,	11.16
Oxide of manganese,	67.60
Baryta,	1.18
Phosphoric acid,	trace
Total,	100.14

XII.

Sample from Saramenha, another deposit.

	Per cent.
Insoluble in HCl,	0.60
Metallic manganese,	60.90

XIII.

Sample from Tres Cruzes, Kilometer 530.

	Per cent.
Insoluble in HCl,	1.50
Metallic manganese,	40.50

XIV.

Sample from Morro do Cruzeiro Ouro Preto, Kilometer 540.

	Per cent.
Insoluble in HCl,	0.7
Oxide of manganese,	65.0
Sesquioxide of iron and alumina,	20.0
Corresponding to	
Metallic manganese,	46.8

Dr. Olyntho continues:

" The above-mentioned deposits are all upon the Ouro Preto branch of the Central do Brazil railway. Besides these there are others, not only along the line itself, but also at short distances from it. The Gandarella basin is one of the most interesting of this district."

XV.

Sample from Gandarella, 20 *km. from the Railway at Kilometer* 551.

	Per cent.
Insoluble in HCl,	2.0
Metallic manganese,	50.7

In the vicinity of Bello Horizonte, the new capital of the State of Minas, 600 kilometers from Rio de Janeiro, beds of great thickness have been discovered.

XVI.

Samples from Acaba Mundo, S. E. of Bello Horizonte.

	I. Per cent.	II. Per cent.
Insoluble in HCl,	6.5	1.00
Metallic manganese,	47.58	56.16

XVII.

Samples from Taguaral E. of Bello Horizonte.

	I. Per cent.	II. Per cent.
Insoluble in HCl,	0.1	0.30
Metallic manganese,	60.09	60.08
Phosphorus,		0.022

XVIII.

Samples from Corumbá, State of Matto Grosso.

	I. Per cent.	II. Per cent.	III. Per cent.
Loss on ignition, . . .	9.85	9.50	8.85
Insoluble in HCl, . . .	1.86	0.65	0.60
Sesquioxide of iron and alumina,	14.40	13.50	12.50
Phosphoric acid, . . .	0.126	0.192	0.126
Metallic manganese, . .	47.52	50.80	51.50

In 1898 a monograph upon Brazilian manganese-ores, entitled *O M[illegible] no Brazil*, by M. Ar-Rojado Ribeiro Lisboa, was published at Rio de Janeiro, pamphlet, 48 pp., and also, June 19, in the *Jornal do Commercio* of that city. This monograph gives analyses of the ore, together with the cost of mining and transportation, from twelve different localities. Being, unfortunately, unable at this time to quote these detailed statements, I substitute (what may be of greater value, as testimony from an entirely impartial source) a statement kindly furnished by Ledoux & Co., of New York City, who sample and assay the larger part of all shipments to the United States, giving the average of 40,000 tons of Brazil manganese-ore, as follows:

	Per cent.
Moisture, ...	7.60
Manganese, ...	54.08
Phosphorus, ...	0.03
Silica, ...	1.05
Iron, ...	0.90

In these shipments the different mines are not specified.

While I am speaking of mining in Brazil, I may use the occasion to answer certain questions often put to me by hopeful young miners, prospectors, metallurgists and mining engineers, with regard to the advisability of going to that country.

First and foremost, one should not go there at all unless he goes under a satisfactory contract. That is not the country for ventures.

Don't go into the Amazon valley for any considerable period —contract or no contract.

The language of the country is not Spanish, but Portuguese; and bad Spanish is not good Portuguese. One is utterly helpless there, unless he understands and speaks the language with

some sort of facility. French is of some use in three or four of the largest coast-cities, but up-country it is as useless as Choctaw.

The mining regions of Minas Geraes and the high interior generally are healthful for people of temperate habits. Beer-drinking is not temperance there. New-comers should not arrive in the months of February, March, April or May. In those months, yellow fever is generally at its worst.

Stoping With Machine Drills.*

BY B. L. THANE, SUMDUM, ALASKA.

(California Meeting, September, 1899.)

WITHIN the past few years, the mining industry has taken a new impetus in all its branches. New mines are being opened every day, while old ones, which have been either working at a loss, or have been compelled to shut down, are now gradually being reopened and placed on a paying basis.

This growth and new life is due, in a measure, to the discovery of new mining districts, but the most important cause of the progress is the wonderful advance that has been made in all branches of mine-engineering.

By means of the important inventions and discoveries that have been made in mechanics, chemistry, and electricity, we are now able to work ores which, only a short time ago, would have been regarded as worthless. We find, for instance, the electrician eliminating two of our greatest difficulties, those of distance and superior elevation, while the mechanic has brought to the highest degree of perfection, not only ore-crushing and hoisting machinery, but all such devices as pertain to the mechanical handling of ores, and, at the same time, the metallurgist, with his combined chemical and mechanical skill, has helped us to extract the precious metals from the most refractory of ores.

But when we turn to examine methods in actual use for

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* Published also, by permission of the Council, in the souvenir volume, "California Mines and Minerals" (see Proceedings of the California Meeting).

mining or breaking ore, we are surprised at the small amount of progress that has been made in this direction. In the handling of the ore after it is broken, almost everything has been done to reduce the operation to its simplest and cheapest mechanical form, and every form of engineering skill has been brought to bear upon the problem. But the work of the engineer usually ends with the erection and installation of the machinery that he has designed. His interest rarely reaches to the details of breaking ore; this is supposed to be the peculiar province of hand-labor. This branch of the business is usually under the immediate supervision of men risen directly from the ranks, who have learned to do exactly what was done before them, and, assuming without question that this is the only method, have bent their energies towards bringing that method to the highest degree of perfection.

There is no intention of denying the value of such work; for it is done well, and the energy, system and skill with which it is carried on are all of the highest order. But this does not prevent one who has marked the revolution which mechanical devices have wrought in other branches of mining from wishing to see the proper appliances brought to bear upon the problem of breaking ore.

The use of power-drills in stoping is one of the methods that have been proposed to solve this problem. Although their use for this purpose is not new, the method has not, in my opinion, received the consideration that it merits. We find the big machine in the shafts, tunnels and drifts a decided success, and in use almost everywhere; but, when we look for the little one in the stopes and on the vein, we find instead the miner with his hammer, pounding away, just as his fathers did before him. Perhaps I should make some exceptions here, and mention what has already been done in this line, but it has been so little, especially in this country, that it is hardly worth mentioning.

Attempts have been made from time to time, by enterprising men, to use machine-drills in stoping. Most of these, for one reason or another, have resulted in failures; and failure once made is sure to be heralded far and wide, only to be lived down by the slow growth of success.

It was the failure, or, rather, the repeated failure and final

success, of one of these attempts, which I personally witnessed, that led me to become personally interested in this subject; and as it bears directly upon the question before us, I will endeavor to give a brief outline of my experiences and their results.

While working underground in the Chief Mine, at Sumdum, Alaska, I had the good fortune to be placed as helper, or "chuck-man," on one of the small machines, known as a "Baby Ingersoll." It was used for stoping and raising on the vein. This work presented an excellent example of the problem before us, as the vein varied from 1 to 3 feet in width (the most unfavorable for machine work), and the place of working was one of great difficulty, as it lay along the shaft, making any mistakes dangerous and costly. Thanks to my partner, who was a machine-man *par excellence*, no such mistakes were made.

This was the fourth attempt to use the little drill at the mine, and the first to register a success. My partner, who was a late arrival from the Cœur d'Alêne, had found the little drill thrown aside in disgrace, and covered with rubbish. But he knew what it could do, and begged to be allowed to give it one more trial.

Of course, it is out of the question to use the big machine, on account of its size and weight, for stoping in such narrow veins, even though in its own sphere it is already a success. The cause of failure in the use of the small drills had been due, in this mine at least, to the fact that the men who had attempted to work them were used to the big machines, where the strength of stroke and larger size of the hole overcame many of the difficulties encountered by the smaller ones. The latter naturally require more care and skill; but this care and skill is not so great but that any man of ordinary ability can master it.

The drill used by us weighed 170 pounds when mounted on a tripod. We found the latter to be much better than a bar, as it allows greater freedom of motion, something absolutely necessary in following a hole, and takes much less time in moving from one place and setting-up in another. With the machine which we used, the bolts are so arranged that a drill may be driven in any direction by a simple manipulation of the legs of the machine, which is easily acquired by practice.

The chief cause of trouble in machine-drilling arises from the many "slips" and layers of alternately hard and soft rock,

which are found running in every conceivable direction in vein-formations. A drill once started, for instance, will run freely till it strikes one of these slips, which it will, naturally, have a tendency to follow; or, again, if, driven through soft seams, it comes in contact with harder material, it will immediately begin to slip along the new surface. This result, if allowed to continue, will cause the drill to "bind" against the bend in the hole, and will not only prevent the drill from entering the hole, but will hold it fast and prevent its withdrawal. This not only occasions much annoyance and loss of time, but frequently causes the total loss of a hole.

With a big machine, where the power is sufficiently great, the drill is driven ahead and pulled out regardless of the slips and bends, and this difficulty is more easily surmounted; but with the smaller one, constant watch must be kept, and the instant the drill starts to slip or bind, the machine must be readjusted to follow the hole, and the stroke shortened, as in starting. To do this it is seldom necessary to stop, for a perfect understanding of the drill, and between the men working it, allows the chuck-tender to loosen the proper bolts while the machine is still in motion; and as soon as its position is changed enough to allow it to run smoothly, it is fastened again. From personal experience, I think it is not only unnecessary but unwise to attempt to drill holes too deep. This practice is usually the cause of much trouble and loss of time. From 3 to 6 feet is quite deep enough for such work, generally speaking. This is all the more the case, as the time required to move the machine from one place to another is very small indeed.

A tripod necessitates the use of a platform to work on, but as it is very easy to build one out of lagging, this is a matter of small consequence, especially as the planks may be used over and over again; and a platform once built saves time in the end, as it enables the workman to move about freely and rapidly, and with less danger of accident.

So far the economical side of the question has not been mentioned, but simply the practicability of the small machine. With regard to this new side of the question, and a most vital one, it is almost impossible to collect data of any general application, because of the small amount of work that has been done with the small drills up to within the last few years.

However, I am informed by Captain Thomas Mein, recently superintendent of the Robinson mine, in the South African gold-fields, that in that great district the use of small machines, on narrow veins, is an established fact, and is carried on with great success.

In the State of California, I find that, within the last six months, some three plants, of five small machines each, have been put in, of which that of the North Star mine, at Grass Valley, is, perhaps, the best known.

My own experience in this line of work is about as follows:

With the "baby drill," two men, my partner and myself, were able to drill about 40 feet a day in hard quartz, full of slips and seams. This work was done between the hours of 9 A.M. and 4.30 P.M. The rest of the shift was sufficient for us to do all our own timbering, to build our chutes and ladder-ways, to shovel away our broken rock, and to keep the place in ship-shape order.

Circumstances favored me with a good opportunity to compare the machine with hand-labor. During the holidays the compressor was shut down for a week or so, preventing the use of the machines, and for that period we worked in the same stope, using the hammer to drive our holes. This permitted an exceptionally fair and complete comparison. All the conditions were the same for both methods; the rock was the same throughout; the size of the vein and the nature of the working-places were the same; and, as we were situated away from the other workmen, the quantity of rock broken daily by us could be, and was, accurately measured.

The results of the comparison were all in favor of the drill. We found that, as an average of the week's work, we were able to break down by hand-labor just half the ground that we had broken before, in the same time, with the machine; or, in short, that two men are able, under similar circumstances, to do twice as much work with the machine as they can do by hand. There is also another incidental advantage attending the use of the machine, namely, that of improved ventilation. One of the greatest difficulties of the directing engineer is to keep the men properly supplied with fresh air, particularly in making up-raises; and this difficulty is entirely eliminated when machine-drills are used.

It must be evident, from these considerations, that the small machine-drill, properly employed, is practical and economical, so far as labor is concerned.

There still remains to be considered the cost of drills, compressors, power and pipe-line, etc. It is unnecessary to go into these questions in detail, because each case must be settled by itself, with a full knowledge of the situation, source of power, size of plant, etc. But with an abundance of water-power, and the practical elimination of the effects of distance and position, made possible through electric transmission, the running expense for power is very slight, and the first cost of the plant is within the reach of any stable company, financially capable of either opening or running a mine. While a certain increase of initial expense for power and plant is necessitated, the reduction in the cost of labor is one-half greater than would be required to offset this outlay.

The reduction in the number of hands needed for breaking ore resulting from the use of power-drills is one of the chief causes of the [illegible] against the machines entertained by many working miners. But this prejudice is entirely unwarranted; for every cause that increases the output of the miner, and decreases the expense of mining, only tends to open new mines, and enables old ones to increase their force, thus giving plenty of work to any supposed or possible surplus of miners.

On my return to the mine, I hope to secure further and fuller data on this subject, in order to convince others of what I firmly believe myself; for I think it is only a question of time before we will have the "little machine" everywhere high up in the stopes, pounding its way into prominence and success.

Postscript (by Prof. S. B. Christy, University of California).—Through the kindness of Captain Thomas Mein, I am able to add the following extract from a private letter, received by him from the well-known South African engineer, Mr. L. T. Seymour. The letter is dated Johannesburg, March 15, 1899, and the extract reads as follows:

"*Stoping*—Hand-stoping in medium ground, up to 4 feet wide, costs 5 to 6 shillings per ton, with boys (Kaffirs). We are, at the Heriot and Gold Deep, stoping with machine-drills at that price, on 6-foot stopes. Each miner now runs 2¾-inch Ingersoll-Sergeants, or 3⅛-inch Little Giants. As a rule, a drill of this

size costs (without dynamite) from £115 to £125 sterling a month to run, for all expenses, including depreciation and interest. The miners' wages come to from £58 to £63 out of this, or almost exactly half. Therefore, two or three drills, distributing the white wages over them, reduce this cost largely. I believe, in three years' time, we shall do practically all our stoping with small machines on the little stopes, and with large ones on everything over 4 feet. The 2½-inch Little Giant works very well.

"At some mines we make the man in a boys' stope run a small machine as well. On this basis, on a 4-foot 6-inch stope, each small machine stopes 279 tons per month, at a total cost, including dynamite, of 5*s*. 9*d*. per ton stoped; and with the large machines, as high as 960 tons per white man per month, when he runs two drills."

These figures tend to corroborate the position taken by Mr. Thane. Machine-drills have been used in stoping at several mines in California for some time, notably at the North Star and the Utica. Their advantages over hand-labor as to cost will depend almost entirely on the cost of power. Where the latter is cheap, there can be no question as to their advantage. The development of the water-power of the State, which is now going on so rapidly, will be surely followed, in the near future, by the more extensive use of the machine-drill in stoping.

The Bryan Mill as a Crusher and Amalgamator Compared with the Stamp-Battery.

BY E. A. H. TAYS, SAN JOSÉ DE GRACIA, SINALOA, MEXICO.

(California Meeting, September, 1899.)

At the present time, the mine-owner has a number of patent crushers to choose from, when contemplating the erection of a mill; and a number of new ones are yearly brought to notice. We all know that the stamp-mill is the old standard; but several of the patent crushers, especially of the roller-type, are not without their merits.

Having had a working experience, extending over a period of four years, with the "Bryan roller quartz-mill," working alongside of stamp-batteries, I take pleasure in giving to the members of the Institute the benefit of my experience with this mill.*

* SECRETARY'S NOTE.—As the Bryan mill has not been described in the *Transactions*, the following account, compiled from the catalogues and other material

Shortly after the Anglo-Mexican Mining Co., Ltd., of San José de Gracia, had completed its 20-stamp mill, it was found that the plant could be increased to advantage; and a 4-foot Bryan mill was put in. This had been running but two months when I took a place in the works, where I remained for eight months. I was struck from the start with the smoothness of the running of this mill, and the little care it required. The batteries were then crushing through 30-mesh sieves, as was the Bryan mill. At a number of different times I compared capacities, and found that this 4-foot Bryan mill was crushing a little more than two 5-stamp batteries. The first set of irons in the Bryan mill lasted about five months, but the second set did not last so long, and the third set only lasted about three months. The rings were not worn out, but all had to be thrown out on account of the unevenness of the wear, which was also the cause of much

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kindly furnished by the manufacturers, is here given for the information of members.

The Bryan roller quartz-mill is made by the Risdon Iron Works, of San Francisco, Cal., in two sizes, known respectively, from their diameters, as 4-foot and 5-foot mills. The former size only is constructed in sections suitable for mule-transportation in mountain-regions; and it is the 4-foot mill to which this paper relates. Both are alike in principle and construction, consisting essentially in a modification of the well-known Chile mill, having three rollers, instead of one, and a pan permitting a continuous discharge. This pan is an annular cast-iron mortar containing fixed steel dies placed in the path of the rollers. In the 5-foot mill, the rollers are 44 inches in diameter, and 7 inches in width of face, and weigh 3650 pounds each. In the 4-foot mill the rollers weigh about 1200 pounds each; but this weight can be reinforced, if desired, by the use of a "loading-tank" over the driving-pulley. Other details of mechanical construction, intended to facilitate continuous, uniform, convenient and controllable operation, are described by the manufacturers, but (with one exception, mentioned below) need not be specified here. They are all features not found in the original type —the Chile mill—and calculated to adapt that crude apparatus to the conditions of modern practice.

The exception referred to as worthy of special mention is the introduction of plain or silvered copper plates around the central cone of the mortar, to promote immediate amalgamation of the pulp, before it leaves the mill.

Among the advantages claimed for this mill are: economy of power; minimum of wear; ease of clean-up; effectiveness of amalgamation; low cost of foundations, etc.; relative absence of slimes; portability, etc. As to some of these claims, this paper gives the results of practice under certain conditions.

During the past ten years the Bryan mills have been introduced in the United States, Mexico, Lower California, Central and South America, Alaska, British Columbia, Tasmania and Australia. For further particulars as to their construction and record in practice, the reader is referred to the manufacturers.

R. W. R.

trouble; so much so, that I several times heard the manager say he was going to throw it out; and he also condemned it as worthless for quartz-milling.

In September, 1897, I was appointed Manager of the Company; and one of the first things I did was to have the machinist tear down the Bryan mill. This had been running then over two years; and, by reason of the lack of proper attention from the machinists' department, we found that the main or upright shaft and the ball-and-socket bearing had become much worn "out of true," which caused the mill to revolve with a wobble, and was the cause of all the trouble. A new shaft was made from an old cam-shaft, and a new brass bearing was cast. The mill was put up again, as if new; and the result was that it gave perfect satisfaction; a set of irons (rings, tires and dies) lasting about five months. However, every time the mill needed re-ironing it was thoroughly overhauled and babbitted; and the result was that the rings, tires and dies wore out evenly and true. In December, 1898, over a year after the first overhauling, this mill was re-ironed at the end of a run of 156 days. The original weight of the rings had been 560 pounds, and that of the tires 1350. The rings when taken off weighed but 101 pounds, and the tires 235; the two together giving an efficiency of 82.4 per cent., that is, 82.4 per cent. of the original weight had been utilized.

The dies, or bottom lining, weighed originally 994 pounds; and, after the 156 days' run, 497 pounds, having worn but 50 per cent. As these were smooth and even, they were left in the mill, with the new set of irons then put in. This would show that, either the dies are made of a tougher material than the rings and tires, or they are made thicker in proportion than they need to be.

For some time prior to May, 1898, I had been having screen-tests made on the batteries, with a view of getting the maximum crushing-capacity and the maximum extraction as near together as possible. I had found that a round-punched tin screen gave better crushing-output than a wire screen of the same relative size. I had also been testing different-sized screens with different discharges, and found that a No. 4 round-punched tin screen, equal to a 10-mesh wire screen, with a 10-inch discharge, gave us as good all-round results as we could

TABLE I.—*Screen-Analysis of Tailings*, May, 1898.

Batteries Nos. 1 and 2 using No. 4 round-punched tin screens, equivalent to 10-mesh wire. Stamps dropping 7 inches with a 10-inch discharge.

Batteries 3 and 4 using No. 3 tin screens, equivalent to 20-mesh wire, and same drop and discharge as Nos. 1 and 2.

Bryan mill using slot-punched Russia iron screen, equivalent to 30-mesh wire.

No. of Sieve	BATTERIES 1 AND 2.		BATTERIES 3 AND 4.		BRYAN MILL.	
	Stays On. Per cent.	Passes Through. Per cent.	Stays On. Per cent.	Passes Through. Per cent.	Stays On. Per cent.	Passes Through. Per cent.
30	All pulp passes.	All pulp passes.	All pulp passes.	All pulp passes.	All pulp passes.	All pulp passes.
40	0.1225	99.8	0.3897	99.51	0.6735	99.22
50	0.3135	99.5	0.7895	98.72	1.5438	97.68
60	1.2197	98.26	1.3677	97.35	3.4360	94.24
80	3.3865	94.87	5.3320	92.02	7.9010	86.34
100	17.8000	77.08	7.6232	84.40	6.5700	79.78
Through 100	77.0778		84.3979		79.7757	
	99.9200		99.9000		99.9000	

TABLE II.—*Comparison of General Milling-Results of Batteries* 1 *and* 2, 3 *and* 4, *and Bryan Mill under Same Conditions as Above, May*, 1898.

	Batteries 1 and 2.	Batteries 3 and 4.	Bryan Mill.
Average value of heads, per ton	$18.00	$21.72	$22.42
Average value of tails, per ton	$4.99	$4.98	$5.28
Percentage of extraction	72 per cent.	77.07 per cent	76.45 per cent
Tons of ore crushed during month	743	614	503
Amalgam taken from mortars	996.672 oz. Troy.	925.9409 oz. Troy.	417.96 oz. Troy.
Amalgam taken from apron-plates	726.928 oz. Troy.	917.5817 oz. Troy.	1129.13 oz. Troy.
Total amalgam	1723.600 oz. Troy.	1843.5226 oz. Troy.	1547.09 oz. Troy.
Approximate value of amalgam	$9,700.42	$10,375.36	$8,706.94
Percentage of amalgam caught inside.	57.88	50.22	27.02
Percentage of amalgam caught on plates	42.12	49.78	72.98

expect; and I had consequently set these as our standards, for reasons that are partially shown in the tables of comparison given above.

In May, 1898, I had No. 4 round-punched tin screens (equivalent to 10-mesh wire) put on batteries 1 and 2; No. 3 tin screens

(equivalent to 20-mesh wire) on batteries 3 and 4, and the regular 30-mesh slot-punched Russia iron screens on the Bryan mill; and I ran them so for the entire month.

The various results can be gathered from Tables I. and II.

These tailings were taken from the ends of the aprons before they went to the concentrators. I am sorry now that I did not keep the mortar-amalgam and plate-amalgam separate, in order to give more complete data; but, from other tests, I judge that, with the batteries, about 65 per cent. of the values are caught in the mortars, and that about 33 per cent. are caught inside the Bryan mill.

The Bryan mill, as will be seen, compares well as a crusher with batteries; but, from my personal observation, I think it can be improved as an amalgamator; that is, made to catch a larger percentage inside the mill.

As the mill is built at present, a plate is put on around the inside cone in which the upright shaft sits. As the motion of the wheels throws everything to the periphery, it is natural that but a small proportion of the amalgam should get to this central cone. This occurs, however, to some extent, and especially where the stream of clear water washes over it. However, the bulk of the amalgam inside is found around the inside periphery, between it and the outside edge of the dies. It would seem to follow, that the manufacturers should build two types: one of low discharge (as built at present), for crushing only; and one with a plate-rim at least 2 inches higher, arranged so that a 4-inch amalgamated plate could be bolted to the inside edge. If mercury were fed into such a mill with the care with which it would be fed into a battery, I have no doubt that the percentage of amalgam taken from the inside of the mill would about equal that taken from the battery-mortar.

As has been shown, one set of irons lasted 156 days. These cost us, put in the mill at San José de Gracia, $407.76. The Bryan mill has three discharges, and consequently uses three screens. During the run of 156 days, 18 screens were used, or a little less than four per month. These cost $66.89. During the same period, two batteries used shoes and dies to the value of $176.77 and $51.78 worth of tin screens. The cost for wear of iron and screens for the Bryan mill was $3.04 per day, and for two batteries $1.387.

The Bryan mill cost for iron and screens 17½ cents per ton.

The two batteries cost for iron and screens 6 cents per ton.

According to this experience, the general merits and demerits of the Bryan mill, as compared with the stamp-battery, are about as follows:

A Bryan mill plant costs just about what a 5-stamp battery does, and costs about the same to run, but can be got into running order in much less time.

A 4-foot Bryan mill will crush about as much ore as two 5-stamp batteries, working under the same conditions. As an amalgamator of gold-ores, it is the equal of the battery, the extraction being about the same on the same kind of ore.

In itself, the Bryan mill requires less attention, once running, than a battery. It should be stopped five minutes once every six hours for oiling inside journals; and the whole time lost during any twenty-four hours should not exceed one hour.

The wear of iron for the Bryan mill during a 156 days' run was less than that of two batteries during the same time, the loss of the Bryan mill being 2904 pounds, and that of the two batteries 3400 pounds. But, by reason of the higher price of the material used in the Bryan mill, the cost of wear of iron and screens per ton of ore crushed by it was 17.5 cents to 6 cents per ton for the batteries.

As an amalgamator, the Bryan is not quite the equal of the Huntington mill; but it is undoubtedly the best, in all respects, of the roller-mills on the market to-day; and, under some conditions, it is the equal of the battery, especially when soft, free-milling ores are to be treated.

As several papers have been submitted to the Institute during the past year on plate-amalgamation, the following may be of interest:

After a run of four years, the plates of this Bryan mill were taken up and melted into bars; and, though they had been scraped close during the second year, they still yielded $7460.96. These plates were 4 feet wide and 16 feet long (in four 4-foot lengths). They had been silver-plated originally (2.5 ounces to the square foot), and weighed about 100 pounds each. I had each of them melted separately, and the results will be seen in the following table:

TABLE III.—*Yield of Gold and Silver from Old Plates.*

Plate No.	Weight, Oz. Troy.	Fineness, Au.	Fineness, Ag.	Gold, 1000 Fine, Oz.	Silver, 1000 Fine, Oz.	Total Value, U. S. Gold Coin.
1...........	1453.120	161.80	68.35	117.078	49.150	$2449.00
2...........	1351.263	89.30	42.21	55.445	26.531	$1161.96
3...........	1372.700	116.71	50.71	85.218	36.540	$1784.37
4...........	1401.780	143.73	60.47	99.202	41.884	$2075.63
						$7460.96

It would look as though No. 4 should be 2, and 2 should be 4; but they were marked as taken off the apron, and the above is the result, as shown by the assays.

I can account, after a manner, for this difference in richness. It is natural that plate No. 1 should be the richest, as it caught the most amalgam. No. 2 was the handiest of the lot to get at, and was consequently scraped somewhat cleaner each day. No. 4, the last plate, was low, and in an awkward position, being exactly under the [illegible] that ran the mill; and as it always had but little on it, it was lightly cleaned and dressed each day, and the little amalgam it caught had more of a chance to accumulate. I shall shortly have the result of the four battery-plates, and will take pleasure in giving it to the Institute.

American Transcontinental Lines.

BY JAMES DOUGLAS, LL.D., NEW YORK CITY.

(California Meeting, September, 1899.)

I.—INTRODUCTORY.

THIS sketch of the history, geography and topography of the American transcontinental railways is based upon a paper read many years ago by the author before the American Geographical Society, and now re-cast, with numerous modifications and additions required to bring it up to date. It was intended primarily for the information of members and guests of the Institute from the East attending the California meeting; and, with that purpose in view, the Secretary of the Institute compiled,

to accompany it, a Geological Railway Guide for the route which the Institute excursion-party from Chicago was expected to follow. This Guide, largely based upon the excellent manual of the late James Macfarlane, published by D. Appleton & Co., New York, having served its temporary purpose, is omitted in the present issue of the paper.

II.—HISTORICAL AND GEOGRAPHICAL FEATURES OF THE ROCKY MOUNTAIN RAILROADS.

1. Preliminary Explorations.

The Anglo-Saxon race is enterprising, but it cannot lay just claim to being adventurous. Its migratory movements have been made in no spirit of levity, but from strong religious motives, at the bidding of liberty, or under the stress of over-population. Such movements, having their origin in deep racial impulses, have been slow in their inauguration, but irresistible in their progress and permanent in their results. When, therefore, the race occupies territory it rarely abandons it. If it moves less rapidly than more excitable races, its tenacity in the end proves to be in proportion to its inertia.

The progress of the race on this continent is a commentary on these characteristics. Columbus set foot on one of the Antilles in 1492. Within half a century Spain and Portugal sent out over half a hundred discovery expeditions, and explored, with one debatable gap, the whole coast-line of North and South America from Greenland through the Straits of Magellan to the Cedros islands, off the coast of Lower California. Within that period Spain had occupied the principal West Indian islands, conquered the empire of the Aztecs and the Incas, crossed our continent from Florida through Texas and Chihuahua to the Pacific, and ascended the Mississippi to the buffalo country. From the Pacific coast of our continent the Spaniards had penetrated through Arizona into New Mexico and Colorado. On the west coast of South America all the country under the sway of the Incas, including a large part of Ecuador, Peru and Chile, was actually brought under Spanish rule, and Spain and Portugal were already rivals in discovery and occupation on the east coast of the continent. Meanwhile Portugal had doubled the Cape of Good Hope and opened up trade with the East Indies.

Such a chapter of geographical discovery throws all modern records into the shade.

That paroxysm of adventurous discovery in the fifteenth and sixteenth centuries hardly touched England. Two expeditions under the Cabots, and another in 1527 to discover the North-west passage, all comparatively barren of results, were her only recorded contributions; and France played a hardly more conspicuous part. Jacques Cartier's story of his voyages did not stimulate the peasantry of France to expose themselves to snow and frost and scurvy, while the unwelcome revelation that his gold was mica and his diamonds quartz crystals removed any temptations which the French nobles may have felt to emulate the methods so successfully pursued by some of their Spanish brethren of recruiting their fortunes by discovery and conquest in the New World.

But in the seventeenth century we find the *rôle* of discoverers being played by the French. The English have founded a string of colonies along the inhospitable seaboard of New England and the hardly more attractive coast of Maryland, Virginia and the Carolinas; but their efforts are all directed towards making comfortable homesteads in the wilderness, framing representative systems of municipal government, and securing political rights from the mother country.

A small Dutch colony has planted itself on the Hudson, but home was even dearer to the Dutchman than to his rival, the Yankee. Spanish enterprise has been completely stifled by the extortion and grasping colonial policy of the crown. But the French have occupied Jacques Cartier's discoveries, and French traders, hand-in-hand with French missionaries, are penetrating the very recesses of the northern continent. Already long before the close of the seventeenth century, and when the English are commencing to open up by sea a trade in furs with Hudson Bay, the French have established missions and trading-posts as far west as the head of Lake Superior; and their *coureurs de bois*, adopting Indian ways and marrying Indian wives, are wandering through the Rocky mountains and bringing back stories of the sources of the Missouri. The different spirit actuating the different people is well expressed in their varying habit of adaptability. A Virginian churchman or a New England puritan populating the West with half-breeds would be an

anomaly we cannot, by the utmost stretch of imagination, even conceive of.

A century later, at the time of the collapse of the French power in America, we find the English colonies as lethargic as before. The Hudson and Mohawk valleys had brought the English and Dutch of New York into contact with the French, and into competition with the French fur-trade, but the traffic was apparently uncongenial, and not pursued with energy. English enterprise here and elsewhere seemed to be sea-bound. It was unable to leap the Alleghenies.

The delusion with regard to the Southwest passage had been dissipated, the Pacific coast to the extreme north explored, and a wide extent of undeveloped continent thus known to be between the two oceans; but what it contained was gathered only vaguely from the stories of the *coureurs de bois*, and such reports of Hudson Bay agents as escaped from their well-closed archives. Not a single Englishman had described, if he had crossed, the continent from sea to sea.

It seems absolutely incredible that a community of England's hardiest and most intelligent sons should have been content to remain for two centuries hemmed in between the sea and the Alleghenies, uninspired by the slightest curiosity to know what filled the great gap of three thousand miles between their home and the western sea, or to explore, in its northern extensions, the mountain range from which the Spaniards were gathering gold, and freighting their galleons with silver.

Carver in 1766–67–68 explored the head-waters of the Mississippi, and described the country north and northwest of the head of Lake Superior, already long and well known to the French. He tells stories of the tribes reported to live to the west of the Shining mountains, who had gold so plentiful that they made their most common utensils of it. These rumors stimulated him to try to cross the continent. More than one attempt failed before the War of Independence, breaking out, frustrated his and his companion Whitworth's final plans.

Mackenzie, in 1789–93, following the wonderful waterway which, north of the British line, links the waters of Lake Superior with the Pacific by the intervention of but few unimportant portages, traversed the continent from sea to sea, and penetrated the Rockies, by the Peace river, almost to the Pacific.

The American government, to relieve itself from the opprobrium of ignorance, despatched the Lewis and Clark expeditions in 1805. These officers of the U. S. army ascended the Mississippi almost to its source, crossed the divide near the line of the Northern Pacific railroad, descended the Clark fork of the Columbia, and reached the Pacific by the main stream, returning the following year in divided parties so as to explore more territory. Yet so small a portion of the vast region did they describe, and so vague was the information to be derived from other sources, that when Astor equipped his expedition by sea and land in 1812 to secure the fur trade of the Columbia, Mr. Hunt, who led the overland party, was in a *terra incognita* from the time he left the Missouri, which he unfortunately did at a point apparently not far from Yankton, till he reached the mouth of the Columbia. Even such salient geographical features as the course and character of the great rivers were unknown to any member of the party—hence the cardinal mistake of supposing the Snake river to be the main stream of the Columbia, and of abandoning their land transport-service on a navigable stretch of that river, far above permanently navigable waters.

But while Lewis and Clark were exploring the head-waters of the Missouri, another government expedition under Lieutenant Pike first described the whole Mississippi river, previously known only at intervals, from its rise to its junction with the Missouri. He is the same lieutenant—afterwards Colonel Pike—whose name is so intimately associated with Colorado; for besides giving it to one of Colorado's magnificent mountains, he first, in 1806, ascended the Arkansas, and cutting across the San Luis park struck the upper waters of the Rio Grande. To him also the world owes its first knowledge of the country drained by the Platte. It was, of course, not till after the purchase of Louisiana, at the commencement of this century, that the government took steps to acquire some knowledge of the margins of its vast domain. But certain sections have remained so secluded that Custer's military expedition to the Black Hills of Dakota in 1874, only 25 years ago, gave us the first accurate information about that important region.

The old Spanish settlements and towns on the Rio Grande

and in southeastern Colorado were linked to California by pueblos, such as Pueblo Viejo, Tubac, Tucson, and thus a through route from eastern United States settlements to the Pacific by the Santa Fé trail had been always open through Spanish territory. As we have seen, the early Canadian and United States explorers, in looking for roads across the continent, naturally followed the great water-ways of the Missouri and Saskatchewan to such points on the Pacific as the mouth of the Columbia, whither trade relations drew them. Thus the great central zone, where the Rockies attain their grandest development, and are not penetrated or even approached by any navigable rivers, continued to be the dark spot of the continent, utterly abandoned to the red man and trodden by only such daring trappers as Bridger.

The exploration, therefore, of our own continent was incredibly slow. But as in other directions, if we are slow to move, when we do move we move to some purpose. The Spaniards explored with the sword in one hand and the cross in the other, but left only trails behind them. We, with pick and shovel, are obliterating their trails by railroad beds.

As the northern trail was that taken by the earliest emigrants who led the way to Oregon, its advantages as a railroad route were so apparent that as early as 1835 a railroad from the upper Mississippi to the mouth of the Columbia was actually proposed. But the project was not acted on seriously till 1845, when Asa Whitney nearly succeeded in securing from Congress a land grant in aid of the first Northern Pacific, before which more recent grants dwindle into insignificance.

In 1848 the Mormon exodus from Illinois and the occupation of the promised land of Deseret was completed, and the country was surprised at learning that in the heart of the great American desert a land existed which flowed with milk and honey, and only waited to be cultivated. The government, therefore, in 1849, undertook a survey of the great basin under Captain Stansbury and Lieutenant Gunnison.

In 1848 gold had been discovered in California, in the year of its transfer from Mexico to the United States, and the adventurous spirits of both hemispheres flocked thither. To most, the straightest road was the best. Neither the high walls of the Rockies nor the snowy summits of the Sierra Nevada could

deter them. California, not Oregon, henceforth became the objective point of the emigrant, and railroad projects now pointed to California, not to Oregon.

The government in 1852–54 sent out surveying parties in search of railroad routes across the mountains. Their work, as embodied in the famous document issued by the war office (Jefferson Davis being Secretary) from 1855 to 1960: "Reports of Explorations and Surveys to Ascertain the Most Practicable and Economical Route for a Railroad from the Mississippi River to the Pacific Ocean," covered preliminary surveys of five possible railroad-routes, as follows:

(1) A route was surveyed by Gov. Stevens and Captain Geo. B. McClellan along the 47th and 49th parallels, which nearly corresponds with that now followed by the Northern Pacific.

(2) Captain Fremont, Stansbury and Lieutenant Beckwith surveyed the country between the 41st and 42d parallels, and proposed a route not widely different from that selected for the Union and Central Pacific railroads.

(3) Captain Gunnison lost his life at the hands of Indians, or of Indians and Mormons, while trying to trace a practicable road along the 38th and 39th parallels, through the sea of mountains which the Denver and Rio Grande and the Rio Grande and Western railroads now traverse between Pueblo and the Salt Lake valley.

(4) Lieutenant Whipple surveyed the country now opened by the Santa Fé Pacific railway, near the 35th parallel.

(5) Captain John Pope, Lieutenant Parke and Major Emory described the route along the 32d parallel, now occupied by the Southern Pacific railroad, which the Secretary of War recommended as the most desirable on the score of length, climate and gradients. The extension of this route, from the mouth of the Gila to San Francisco, was explored by Lieutenant Williamson.

2. Railway-Building.

The State of Missouri was the first to charter a transcontinental route, under the name of the Missouri and Pacific R. R. Co. It was to start from St. Louis, and, after running southwest, to follow the 36th parallel through the present Indian Territory to Santa Fê, and thence across to the Pacific. The civil war frustrated this scheme, but hastened the accomplish-

ment of another. To build a road through a region within the radius of active war was hazardous. Yet California, isolated from the rest of the States, it was seen, must be brought within rapid reach of the central power. Hence the organization of the Union and Central Pacific companies, and the liberal assistance tendered them by government, to build a road from the Mississippi to the Pacific, far north of the strife then raging. The charters were signed in July, 1862; the first sod was turned on the Central Pacific February 23, 1863; but work was not commenced on the Union Pacific until November 12, 1865, after the immediate cause for urgency had passed. Fourteen years, or to July, 1876, was the limit of time allowed by the charters for the completion of the joint enterprise; but the eastern and western sections met, and the last spike was driven at the station of Promontory, on May 10, 1869.

This station is 1084 miles from Omaha, but only 850 from San Francisco. Yet, taking into account the much greater engineering difficulties which beset the Central road in crossing the Sierra Nevada than those which obstructed the Union road in the Rocky mountains, as much credit is due to the one as to the other.

In 1864, before work on the Union Pacific railroad had been commenced, the Northern Pacific R. R. Company obtained a charter. Governor Stevens' survey in 1853 of the northern route had proved its practicability; but this company, organized by Mr. Perham, sought in vain for financial assistance till Jay Cooke & Co. came to its rescue and effected thereby their own ruin. Construction was commenced in 1870, but, by reason of many financial vicissitudes, the road was completed only in 1883.

But individual energy had been at work in the extreme south of our western domain. Before this date the Southern Pacific had been opened from end to end. While the Texas and Pacific Co., chartered in 1872 to construct a road from Fort Worth in Texas to San Diego on the Pacific, was languidly building from the east, and vigorously soliciting government aid, the large stockholders of the Central Pacific were constructing a line with their own resources, along the proposed route of the Texas and Pacific from the California end. And thus before the Texas and Pacific had laid their tracks through

the State of Texas, the Southern Pacific had occupied Lower California, Arizona and New Mexico, and united with the Texas Pacific proper in Texas at the end of 1882. Contemporaneously, the Atchison and Topeka, originally a road looking for support to the agricultural resources of Kansas, had crossed the Raton spur of the Rockies, earned the right of adding Santa Fé to its title, and, by connecting with the Southern Pacific at Deming, created another Rocky mountain railroad. Since then this company has made an independent outlet for itself to the Pacific at San Diego, by the Atlantic and Pacific R. R. (now the Santa Fé Pacific) and the California Southern.

While these broad-gauge roads were seeking for valleys and easy grades by which to cross the mountains, a narrow-gauge road (controlled by officials, and constructed by engineers, with very broad-gauge ideas), the Denver and Rio Grande, was successfully combating difficulties and scaling heights which only lavish expenditure of money, handled by the highest engineering skill, could overcome. This road was intended to be a link through the valley of the Rio Grande, between the Southern and Central systems; but the Atchison and Topeka forestalled it. The management then divided its energies between fighting the Union Pacific and reaching the most inaccessible regions in Colorado. The marvellous feats which its builders have really accomplished are as wonderful as those the Union Pacific was supposed by popular imagination to have performed. Though commenced as a narrow-gauge through-line via Pueblo and the Royal Gorge with, subsequently, a branch to Leadville, it was completed by an independent company from Grand Junction to Salt Lake City as a standard-gauge road, under the title of the Rio Grande Western R. R. At present it makes connection with the Colorado Midland, by which it secures a standard-gauge track from Denver to the Great Basin. But it of necessity retains the 36-inch gauge for its line over Marshall pass, and its many tortuous branches. The last road to link the waterways of the Atlantic coast with the Pacific is the Great Northern. Begun as the St. Paul, Minneapolis and Manitoba, to afford railroad facilities to the rich Red River valley, it was extended into Montana in 1887, and has reached Puget sound at Everett, and tapped the mining regions of British Columbia. Other western roads are pushing across the continent, the Chi-

cago and Northwestern taking the lead; all the railroad companies recognizing the fact that the trade with Asia is certain to be an increasing factor in our commercial life.

3. General Geography and Topography.

The geographical and topographical features of those sections of the continent which these roads traverse, as exhibited in their profiles, are laid down in the accompanying map.

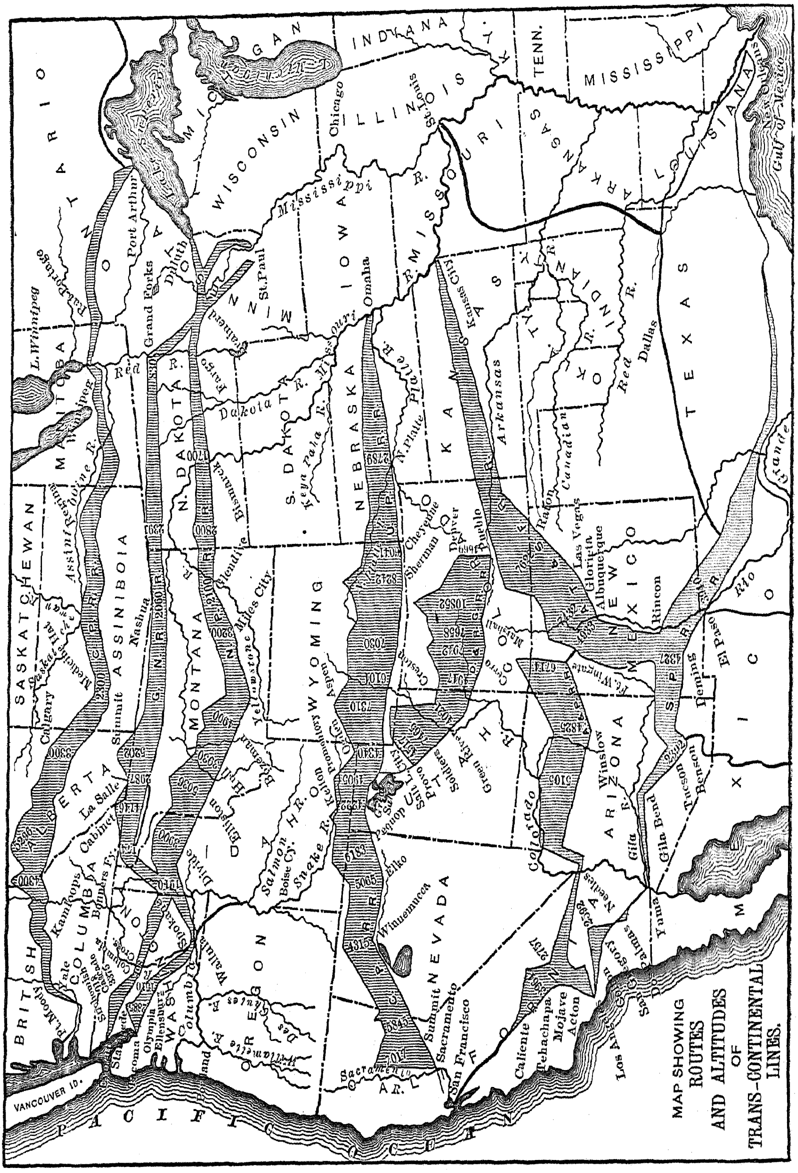
The Rocky mountains, including the whole system of mountains and plateaus from the plains as far as the Pacific coast, attain their greatest development in height and width along the 41st parallel, which nearly coincides with the line of the Union and Central Pacific railroads, and there exhibit with marked prominence all their features, the principal of which are high and steep eastern and western chains, the Rocky mountains to the east, and the Sierra Nevada to the west, enclosing an elevated plateau corrugated by diagonal minor ranges. To the west of the western rim is a coast valley, itself protected from the sea by a Coast range. This structure, with such variations as nature loves to indulge in without departing from uniformity of type, is maintained along the west coast of both North and South America, as well as in the structure of other continents. It is well illustrated in the sections made by the Rocky mountain railroads. In fact, until railroad-surveys were made, accurate topographical maps of extended regions had been, probably, nowhere produced.

4. The Union Pacific Railroad.

The profile of the Union and Central Pacific roads exhibits these features better than that of any other road. The plains rise by a grade, so easy as not to be appreciable to the eye, from 968 feet at the Missouri to 6038 feet at Cheyenne, or 5070 feet in 516 miles, the country changing with the decrease in rainfall from the rich fertility of the Nebraska prairies to grazing lands, dry and seemingly valueless, but able formerly to support the buffalo and now their tamer successors.

At Cheyenne the Laramie hills rise abruptly from the plain; but, like all hills looked at from below, the steepness is illusory, for the train scales them to Sherman, a point 8235 feet above the sea, in 33 miles, and then descends into the Laramie plains,

whose average elevation is about 6500 feet. This is in reality the most northerly of the parks, though not generally ranked among them. The plains are well watered by rivulets which



MAP SHOWING ROUTES AND ALTITUDES OF TRANS-CONTINENTAL LINES.

flow north into the North Platte, the main stream of which is separated from the plains by a ridge 7168 feet in altitude, over which the road runs before ascending the Continental divide,

here only 7100 feet above sea-level, and therefore more than 1000 feet lower than the summit of the Laramie hills at Sherman, and but 500 feet above the average level of the rolling plains which intervene. To the north and south high mountain ranges break the surface of the plateau, but the profile shows what an easy highway nature offered the railway builders across the great basin on this parallel. It was always the Indian's and trapper's trail, and was in 1852 suggested by Lieutenant Gunnison as a feasible railroad route before the official survey.

To the north and northwest can be seen the Seminole mountains, the Sweetwater range, and in the far distance the Wind River mountains; to the south the Elkhead mountains, and away to the southwest the spurs of the Uintah range. From the summit there is a down grade to the Green river, for 60 miles of the way along the Bitter creek, through an utterly desolate region, the cliffs on either side encroaching close on the valley. The sandstones which here accompany the coal that underlies Wyoming, east and west of the Divide, favor the sterility which elevation and drought alone are enough to produce, but add to the scenic effects by weathering into picturesque bluffs. The Green river, one of the great branches of the Colorado, is the first and only large stream which flows into the Pacific, along this parallel, till the Sierra Nevada is passed; the river and lake system of each section of the great basin—the Utah section and the Nevada section—being self-contained.

The Uintah range, whose axis is nearly east and west, is now the conspicuous feature to the south, its sides covered with forest, and at its base Beaver creek, which was Bridger's favorite trapping-ground for the American Fur Company as far back as 1820. Up the Big Muddy the railroad now ascends a spur of the Uintah, crosses it at Aspen at an elevation of 7835 feet, and descends into the valley of the Bear. This stream, like many others in the Rockies, doubles on its own course. It rises to the south of the track, flows north, outflanking the Wasatch range, and returns south to discharge, after a course of 230 miles, into the Great Salt lake, not over 60 miles west of its source. But the railroad-builders tunneled the high jagged range at Wasatch, and carried the track through the wonderful rock scenery of Echo and Weber Cañons, down the

steep western slope of the Wasatch to the Salt Lake valley at Ogden. To secure some of the traffic of the Northern Pacific states, and gain closer access to the sea, the Union Pacific built the Oregon Short Line, which runs diagonally through parts of Wyoming and Idaho from Granger in the former state to Huntingdon on the Snake river, where it connects with the Oregon Railroad and Navigation Co., which affords the most direct route to Portland via the Columbia river.

Five roads radiate from Ogden: the Union Pacific towards the east; the Central Pacific towards the west; the Denver and Rio Grande towards the southeast; the Utah Central runs due south down the valley; and the Utah Northern, built first as a narrow-gauge road, but, in consequence of the extraordinary growth of Butte, converted into a standard-gauge, runs due north through the eastern section of Idaho into Montana, where it connects at Garrison, at the western foot of the Rocky mountains, with the Northern Pacific. But the original, and still the main connection of the Union Pacific, is with the Central Pacific.

5. The Central Pacific Railroad.

From Ogden westward the Central Pacific, after crossing from the Utah into the Nevada depression of the Great Basin, descends by easy grades to the eastern foot of the Sierra Nevada, through a region even more desolate than that traversed by the Union, between naked mountain ranges, over long stretches of rolling sage-brush plains, hardly redeemed from utter sterility by a ribbon of verdure on the banks of the Humboldt river. The railroad follows the valley of this river from Moore Station for a distance of 350 miles till it enters the Humboldt lake, and flowing thence, loses itself in the sink of the Carson.

The profile shows this westerly basin, occupied by the Humboldt and other lakes, to have almost the same level as that of the Great Salt lake. Into it flow the Humboldt from the east and the Carson and Truckee rivers from the west, all perennial streams [illegible] large bodies of water; but the thirsty sands and the rapid evaporation from the lakes, which these rivers form, drink up all they contribute. Carson lake, which, like the Great Salt lake of Utah, is the residuary recipient of the whole river and lake system of this portion of the Nevada desert, has no outlet. The valley of the Truckee was selected

by the railroad engineers as the most feasible route out of the basin. In approaching the valley of the Truckee, the railroad traverses, from Lovelocks to Wadsworth, for about 63 miles, a desert region white with alkali, and full of solfataric activity, bubbling with hot springs, which are saturated with soda and borax, and underlaid by beds of brimstone. Thence it follows the narrow channel of the Truckee (too barren generally to produce much, even with irrigation) to the town of Truckee, a distance of 62 miles, gaining an elevation in that distance of 1742 feet. At Truckee commences the pull up to the summit, a distance of only 14 miles, in which 1198 feet of elevation are gained. The scenery of Donner lake, which the train skirts after leaving Truckee, the piles of mountains rising more than 3000 feet above the tunnel by which the road cuts through the crest of the Sierra, and, on the western side, glimpses of the birth and growth of the streams which dash down through the forests to feed the Sacramento, give this section of the road pre-eminence in beauty; but what between tunnels and 50 miles of snow-sheds, the traveler is kept in a state of constant irritation—as angry as when, in New England, expecting to get the full view of a beautiful river, he enters a covered bridge. Down the western slope of the Sierra the train speeds from the summit at 7017 feet to Colfax, a descent of 4595 feet in 51 miles, through the pines, into the oak glades, and down to the plains. The relief of passing at a bound from the most desolate spot on the continent, the Humboldt desert, into one of the most fertile of the world's valleys, that of the Sacramento, is intense. The Coast range does not appear on the profile, because the railroad terminates on the Upper bay formed by the junction of the Sacramento and the San Joaquin rivers, and this great harbor is carved out of and sheltered by the Coast range, on whose hills San Francisco itself is built.

6. The Denver and Rio Grande Railroad.

The Denver and Rio Grande, as already observed, surpasses all competitors in the feats of engineering its builders have achieved. Each of its branches was, at the time of construction, the most remarkable deed of daring yet attempted, and each successive effort has surpassed its predecessors in boldness of conception and execution.

Our map would be covered to confusion, were we to attempt to show each of the Denver and Rio Grande lines.

The first mountain branch was that over the Sangre de Cristo range by the Veta pass, thence across the San Luis park and down the valley of the Rio Grande to near Santa Fé. From this two feeders diverge to the San Juan and to other as inaccessible mining localities, heretofore deemed difficult of approach by ordinary vehicles.

The main line, as originally located, ran from Pueblo, over the Marshall pass, to Salt Lake. The gauge was 36 inches, and it was expected to be the forerunner of many another 36-inch road—an anticipation which has not been realized.

In its course it cuts the Rockies at their highest and wildest, to the west of Pueblo, taking advantage of the Arkansas to reach the water-shed of the continent at Marshall pass.

The Royal Gorge, in the Grand Cañon of the Arkansas, is the portal which admits the traveler from the plains into the recesses of the mountains where the river receives its life. Above the cañon the valley widens, and is productive of grasses and of such vegetables as the great altitude permits to come to maturity. At Salida the branch to Leadville continues up the Arkansas, but the main road ascends the Saguache range to the Continental divide. This is crossed by Marshall pass at an elevation of 10,820 feet, by grades reaching 220 feet to the mile.

From this great elevation the eye wanders far and near over forest-clad mountains with rounded outline, less startling, perhaps, but more pleasing than the bare sides and jagged profiles of the Eastern and the Sangre de Cristo ranges, for colors and curves are principal elements of beauty. If they do not elicit wonder, they excite pleasure. Nature when clad in neutral tints is bereft of half her charms. Looking from this vantage ground it would seem impossible that the railroad could find a path through the network of ranges, the peaks of which tower to north and south and east and west to elevations of 12,000 and 14,000 feet—not one peak, but many. Yet though the road follows river-courses, they are not always river valleys, but deep, steep gorges, over whose stony sides the engineers had to be suspended in locating the road, and the miners in dislodging the rocks to gain a footing for the road-bed.

The Tomichi river, the main confluent of the Green, is reached almost at once after the Divide is passed, and where this branch unites with its northern sister to form the Gunnison, is rising the city of Gunnison, at an altitude of 7680 feet. Below Gunnison the river cuts through mountain and plateau, creating the Black Cañon of the Gunnison, less gloomy than the Grand Cañon of the Arkansas, and enlivened by a greater variety of rocky outline, for the gorge has been carved out of limestones and sandstones, instead of riven through the old crystalline rocks. It is broader, and is streaked with color derived from the weathering of the rocks, as well as from vegetation. The Gunnison Cañon becomes more rugged below Gold creek, and rather than follow it the road crosses Squaw mountain and joins at its western base the Uncompahgre branch of the Gunnison. This it follows to its junction with the main river at the town of Delta, and it still keeps to this highway of nature across the Grand mesa till it unites with the Grand river at Grand Junction. For 200 miles farther westward the Rio Grande Western road ascends a series of barren steppes before surmounting the Wasatch and entering the Great Salt lake valley. From Grand Junction to the Great Basin, the Rio Grande Western is of broad-gauge. At Grand Junction the (originally narrow-gauge) Leadville branch of the Denver and Rio Grande, which leaves the main transcontinental line at Salida, rejoins it, after having tapped Leadville, crossed the range by the Tennessee pass, and connected with the Aspen district via Glenwood Springs.

The Colorado Midland, a standard-gauge road, which runs from Denver through Colorado Springs, Manitou, and Buena Vista to Leadville, follows a parallel route to the Denver and Rio Grande from that point to Grand Junction. Leadville, therefore, enjoys the services of three roads—the Denver and Rio Grande, a branch of the Union Pacific, and the Colorado Midland.

7. The Southern Pacific Railroad.

The Southern Pacific is now the only United States railway whose termini are on the two oceans—the eastern at New Orleans, the western at San Francisco. It runs through the swamps and across the bayous of Louisiana, over the low coast lands of Texas to Houston, and thence traverses from east to west its fertile cotton-fields to beyond the old Spanish

town of San Antonio, where the land grows less fertile. At 170 miles from San Antonio the road enters the Cañon of the Rio Grande. Through this it is built on benches overhanging the river, and within a stone's throw of the Mexican shore, till it reaches the undulating limestone plateau through which the river has cleft this narrow trough. On the plateau the scenery differs from that of the plains to the north only in the vegetation which clothes it. We are on the "*Llanos estacados*," the "Staked plains" of other days. Though no river runs for hundreds of miles through this dreary waste, springs occur, and water in many places is pumped to the surface to supply the cattle and sheep which roam over this scorched wilderness. These, though necessarily few in number to the mile, are an immense multitude in the aggregate. Not a hill breaks the horizon for more than a hundred miles, but the road ascends gradually to Sanderson, where short isolated ranges commence to rise out of the plateau, and the mountain scenery assumes the aspect which it henceforth bears along the line of road all through New Mexico and Arizona, till the Colorado is passed and the Yuma desert is entered. This company operates to-day the Central Pacific to Ogden, Utah, as well as the through line from Portland, Oregon, to San Francisco, Los Angeles, and New Orleans, with many branches, comprising nearly all of the railroad-system of California.

The Rocky mountains, as we have seen, attain their grandest development in Colorado. In northern New Mexico they still maintain their character as an unbroken Cordillera. But further south it becomes impossible to identify the features which we have seen the continent to possess along the 41st parallel. In western Texas, central New Mexico, and in northern and central Arizona there is a complicated system of short ranges so interlocked as to leave but narrow valleys between; while in the southern portion of these territories similar ranges, with a general northeast and southwest axis, spring from the lofty plateau, whose average elevation is about 4000 feet, in isolated mountain masses, with great stretches of intervening plain. The Texas Pacific railroad has crossed the same plains to the north of the Southern Pacific, and entered the same mountain scenery in its straight course from Fort Worth to Sierra Blanca, where, at 91 miles from El Paso, on the Rio Grande, it unites

with the Southern Pacific. Westward the single railroad winds among these miniature ranges without, as the profile shows, any great variation in grade, and yet by a route so tortuous that long stretches are built to reach points a few miles apart. Mountains with bare flanks, but crowned by a fringe of pines, before and behind, and on either side, close in every view, while yet the train is gradually crossing a plain of sandy or baked reddish soil, sprinkled with tufts of grass and dotted with soap-weed or yucca, bushes of grease-wood, and groves of mesquite, and in places groups of huge cacti and smaller members of the same grotesque family. Only two rivers, the San Pedro at Benson, and the Santa Cruz at Tucson—the latter generally dry—are crossed between the Rio Grande and the Colorado, a distance of 550 miles. The Rocky mountains have been completely shattered, and their scattered fragments seem to strew the plains. They reunite in the Sierra Madre of Chihuahua, immediately south of the line, recover from their disorder, close up their ranks, and present an unbroken front southward to the Isthmus; but in New Mexico and Arizona they have been completely obliterated as a Cordillera.

The Rio Colorado is crossed at 60 miles above its mouth, where it flows between low, sandy banks; for the Grand Cañon has terminated hundreds of miles above, before the river has turned from its east and west to its north and south course. Before reaching the river the country traversed has become, if possible, more forlorn, and desolation reigns supreme. After the bridge is crossed the Yuma desert is entered. In traversing it the train runs for hour after hour over plains of sand, 30 miles of which are below sea-level. At all seasons a *mirage* is seen, as tempting as any which deludes the African traveler. At places the sandy surface is flat, at others it rises into hillocks like the dunes of Holland. Fields of pure white salt and alkali alone break the color-monotony of the yellow sandy plains and sun-baked mountain ranges. The San Bernardino mountains rise steeply ahead, their slopes as bare and rocky as the mountain ranges between which we have been passing now for over 1000 miles. They represent the Sierra Nevada mountains, which, along this zone of the continent, dwindle, like the Rockies, into insignificance. Further south they continue to

assert themselves, but still more feebly, in the peninsula of Lower California, before being lost in the Pacific.

As we ascend the eastern slope of the San Bernardino range, the desert merges into arable land, but the summit of the Gorgonia pass is so speedily reached that the train seems to leap as if by magic from dreary sterility into the orange groves of Colton and Los Angeles and the rich verdure of the San Fernando valley. Here the Coast range to the west is well defined; but the coast valley in which this oasis is enshrined rapidly contracts to the north, and the Sierra Nevada and the Coast range coalesce into a network of cross-ranges through which the selection of a practicable railroad route was no easy task. That selected passes from the head of the valley easterly through the Soledad pass into the Mojave desert, the northerly representative of the Yuma desert, over which we traveled, and then returns, through a maze of mountains, over the Tehachape pass northwesterly into the great longitudinal coast valley. In crossing the pass the grades are reduced by making the road describe the figure ∞ round two adjacent isolated hills forming the well-known loop.

This is the last engineering feature of note in the Pacific section; for the road does not again leave the broad, fertile plain of the San Joaquin valley, closed to the east by the high snow-capped boundary of the Sierra Nevada, enshrining the Yosemite and other almost as beautiful, if not as famous, pieces of scenery, and to the west by the lower wall of the Coast range. The Southern Pacific had been running its trains through to the Atlantic for five years before it connected its Southern California section with the Oregon road, which ran south from Portland through the Willamette valley. That amalgamation and connection made, the Southern Pacific Co. has been in a position to tap by its own track the trade of the whole Pacific coast, almost from Puget Sound to the Mexican line, to drain the heart of the continent by the control of its central section, and to span the continent from the Pacific to the Atlantic. The geographical features of the Shasta division, as the road from San Francisco to Portland is designated, bear a general resemblance to those between Los Angeles and San Francisco. From Sacramento northward the road occupies the

Sacramento valley, corresponding to the San Joaquin valley on the south, between the Sierra Nevada and the Coast range. At its northern head this great interior valley-area of California is enclosed by the Siskyou cross-range of hills, which the road traverses amid magnificent scenery. Thence it passes northward, through the valley of the Willamette, to the junction of the latter with the Columbia, at Portland. North of the Sacramento valley, the mountains (here called the Cascade range) assume grand proportions, culminating in the magnificent peaks of Shasta, Hood and Rainier.

8. The Atchison, Topeka and Santa Fé Railway.

The Atchison and Topeka started as a Kansas prairie-road; but through its ramifications it has become the most extensive of all the mountain railroad-systems.

The mountain-section commences at Trinidad, Colorado, where the road has risen upon the plains from 765 feet at Kansas City, to 6000 feet at Trinidad, in a distance of 652 miles. We have seen that on the line of the Union Pacific, about 180 miles to the north, from Omaha to Cheyenne, in a distance of 516 miles an elevation of 6038 feet was attained. At Trinidad, in the midst of a coal-field extending to both sides of the Raton range, the ascent of this spur of the Rockies commences, and is completed in 12 miles by a tunnel at an elevation of 7622 feet above the sea. The road now issues on those vast rolling plains which spread over northern New Mexico, Texas, and the Indian Territory, and which feed a thousand rivulets that combine to make the Red and Canadian rivers, discharging into the Mississippi, and the Pecos, which helps to swell the lower Rio Grande. The road proceeds south, with the snowy range of the Sangre de Cristo bounding the view to the west. Behind that flows the Rio Grande, and only beyond that again rises the Continental divide. Over it the line does not pass, for after crossing the plateau for 175 miles at elevations varying from 5000 to 6600 feet, it mounts the Sangre de Cristo range (here the Glorieta), descends into the valley of the Rio Grande, and follows it for 300 miles to the Mexican frontier town of El Paso.

9. THE SANTA FÉ PACIFIC, FORMERLY THE ATLANTIC AND PACIFIC RAILROAD.

But at the old Spanish town of Albuquerque, a cross-road branches west, which completes the transcontinental character of the Atchison and Topeka. It was built as a section of the St. Louis and Pacific, which is itself a survival of the old Missouri road, of which I spoke in the historical sketch. It runs for all the distance between Albuquerque, on the Rio Grande, and the Colorado river, at the Needles, through the most mountainous section of New Mexico and Arizona, at a very high average altitude. The Continental divide is passed near Coolidge, at an elevation of 7257 feet, and the road subsequently runs among heavily pine-clad ranges, past the foot of the San Francisco mountains, parallel with, and at one spot not more than 20 miles south of, the Grand Cañon of the Colorado, and over the southern extension of the Great Basin. The Colorado river crossed, the road traverses the same dreary waste which in the south we knew as the Yuma desert, and in the north as the Humboldt desert, ere it joins the Southern Pacific at Mojave Station. The Southern California, which branches south from the main line at Barstow, crosses the San Bernardino range into the fertile San Gabriel valley, and completes the connection of the Santa Fé system with the Pacific at Los Angeles and San Diego.

10. THE NORTHERN PACIFIC RAILROAD.

We have seen that a Northern Pacific railroad was the first proposed, but almost the last built, of the first group of transcontinental roads. As now constructed, its eastern terminus is at St. Paul. Thence it sweeps for 275 miles over the rich prairies of Minnesota, then spans the Red River of the North, pursues its way due west still through the most fertile farmland, crosses the Missouri at Bismarck, and sweeps onward again over deep, rich, black soil, a total distance of about 586 miles from its starting-point, till the Bad Lands of Dakota are reached near the Montana boundary. There it crosses the curve of average rainfall which defines the farming-lands that can be cultivated without irrigation. This curve sweeps northward across the Canadian frontier; but the road stretches westward with the foot-hills of the Rockies. Yet throughout the

whole mountain-zone in this parallel the climate is sufficiently humid in average years to clothe the hill-sides everywhere with nutritive grass, and to fill the valleys with perennial streams,—whence the enormous cattle-ranching capacity of Montana through its entire width of 800 miles.

The Bad Lands are a relief to the traveler, wearied by his long journey over these hundreds of miles of prairie. That these prairies have been laid out into immense farms, and are cultivated by machinery, does not increase their picturesqueness, while it deprives them of that human interest with which we invest the homesteads of families who are trying to deserve a living from the earth, and to return her kindness by adorning her, in their humble way, with trees and fruits and flowers.

The Bad Lands, which the railway guide-books, unwilling to describe this narrow strip of twenty miles as unfit for occupation, ingeniously say were so called by the early French trappers because they were *terres mauvaises à traverser*, not *à cultiver*, owe their character, probably, to the lignite which once underlay them. Here the outcropping beds have become ignited, and, by the heat thus generated, have altered the color and character of the adjacent shales and sandstone, rendering them more liable to erosion by water and wind, the combined influence of which has carved the whole country into most fantastic forms. The great eastern buttresses of the Rocky mountains now loom into view; but the road remains on the prairies, skirting the Powder range till it strikes the Yellowstone river at Glendive. To this valley it clings for 340 miles, as far as Livingstone, where this most important of the northern affluents of the Missouri comes in from the south, having drawn its waters from the heart of the Rockies, and enhanced the beauties of the Yellowstone park. This valley, where followed by the railroad, is narrow, not averaging three miles in width, and enclosed by bluffs sparsely clad with pine, which, though low, are still high enough to shut out all but glimpses of the Big Horn and Yellowstone ranges to the south, which have deflected the river from a straight course between its source and discharge. But each of the rivers which flow into it from the south, fed by the great spurs of the main range, the Powder river, the Tongue, the Rosebud and the Big Horn,

remind us of the last desperate struggle of the dominant nation of the north, the Sioux, against the march of the white man between 1872 and 1877, hastened by the progress of this very railway—a struggle rendered memorable by the daring deeds and untimely end of Custer. In this valley also is a memento of Clark, who, on his return journey in 1806, carved his name on a prominent rock and called it Pompey's Pillar—a name retained for the neighboring railway-station.

From St. Paul to Livingstone the grade has been easy and the elevation low. But the road after leaving the Yellowstone commences to climb the Bozeman range, a spur of the Rocky mountains. It cuts off the summit by a tunnel, at an elevation of 5565 feet, and emerges in a wild gorge which it follows along the stream of the Gallatin to the base of the range. Here it enters the birthplace of the Missouri, an amphitheatre of great hills where the Gallatin, the Madison and the Jefferson unite their waters to form this mighty transcontinental river, which thus springs into existence as a stream of considerable size. We follow its banks for thirty miles, till the Rocky mountains bar the river's further progress westward. It is prevented, however, from reaching by a straight course its destination in the eastern sea by the confused mass of the Little Belt mountains, round which it sweeps through Clark's Gate of the Rockies, due north, over the falls of the Missouri, and thence as a navigable river eastward. The road, after leaving the river, pursues its way westward, crossing the Continental divide through the Mullen tunnel, at an elevation of only 5648 feet.

We are now in the golden land, and almost every valley has been turned over and over in search of the precious dust. The beautiful town of Helena, near the foot of the divide, stands in a wilderness of boulders, heaps and trenches, and the surface of the valleys near Butte, Bannock and Virginia City, and many another spot, looks like the Bad Lands of Dakota in miniature, tossed out of all shape by the myriads of miners who, from 1861, when gold was first discovered in Deer Lodge county, till recently, have extracted from the shallow placers of this section of Montana over one hundred millions of dollars. But little is left in this accessible condition; and what little there is will probably remain unmolested, as the Montana miners have ordered away the Chinese.

The Rocky mountains here, though not of the majestic proportions of the Colorado range, rise high both north and south of the Mullen pass. Along this parallel the range seems to have been, as it were, spliced, the Bitter Root mountains from the south overlapping on the west the main range, which descends from the north. The engineers of the road took advantage of the point where the mass of the range, being thus divided, was reduced in height and a passage was made easy. Tortuously the road ascends the eastern slope of the Continental divide from Helena at 3980 feet to the tunnel, affording a magnificent glimpse of the mountains to the south, which enclose the National park; but the western descent is less rapid into the valley which carries towards the Columbia the waters of the Deer Lodge creek, *alias* Hellgate river (the former the name in the farming section of its course, the latter in the mining). The mountains close in—the Bitter Root mountains on the left, the main range on the right—till the valley is contracted into a gorge, rendered more sombre by the heavy growth of pines which clothe the rocks; for, now that we have crossed the mountains, both plain and hill are forest-clad. Northwest the road runs along the banks of the streams, now swollen into the Clark's fork of the Columbia, unable to escape westward over the high Bitter Root range—bitter indeed to the thousands of penniless prospectors who flocked thither, even from the warm southern territories and Mexico, to seek for but not to gather gold in its snow-clad Cœur d'Alène mines during the rush of 1882. Where Clark's fork expands into the beautiful lake of Pend d'Oreille the road finds egress from the mountains and enters the northern extension of the great plateau, which we have traversed in Arizona, and again when crossing the Great Basin on the Union and Central roads. Only here, as the Rocky mountains point northwest and the Sierra Nevada and their extension, the Cascade mountains, have a slightly northeasterly trend, the great valley has been crushed in, almost to extinction. It is at this point only 100 miles across, and at less than 100 miles farther to the north it ceases to be a well-defined feature of the continent. There the Rocky mountains and the Cascades are built together into the one broad wall, supporting an elevated plateau, against which the waters of the Pacific beat to the furthest limit of the continent.

But though the Great Basin has shrunk to such meager proportions, its contents have grown in value. We are far north, but the warm ocean current, flowing from Japan, carries heat and moisture to the coast, and thus the climate of this section of the State of Washington, even east of the Cascades, so assists the fertility of its soil that the productiveness of this extreme end of the Great Basin almost defies belief. The road cuts diagonally across the basin from the northeast to the southwest, through Spokane, till it strikes the Columbia at Pasco and Ainsworth. From Pasco it continues to cross the basin in a northwest direction, and then ascends the Cascade range to the Stampede pass, at an elevation of 3980 feet. It descends rapidly to its termini at Tacoma and Seattle on Puget Sound.

The Oregon R. R. and Navigation Co. supplies the direct route through Spokane to Portland *via* Umatilla, where it unites with the road from Huntingdon, and the Oregon Short Line. Pasco on the Northern Pacific and Umatilla on the Oregon R. R. and Navigation Co.'s line, are near the great bend of the Columbia, where it turns to break through the Cascade range.

The gorge which this magnificent river has cut through these mountains—the representatives of the Sierra Nevada—for a distance of over 200 miles, was taken advantage of by the railroad builders to make their escape to the sea. The engineering difficulties in the construction of the road in this section were excessive, for so precipitously do the banks rise out of the water below the Dalles that the road-bed had in places to be carved out of the rocky escarpment. The old Oregon trail reached the Pacific by this route, but the obstacles to road-building were so great that the emigrants never attempted to force a passage by wagon below the Cascades. The railway was the first road of any kind on the banks of this stretch of the lower Columbia.

The Cascades here soar into magnificent proportions, a number of peaks rising above the snow-line, such as Rainier (Tacoma), 14,860 feet, and Mt. Hood, 11,025 feet.

Portland is on the Willamette river, a large stream which flows from south to north down the coast valley, and joins the Columbia at the bend, where it turns northward to seek an

outlet through the Coast range. Here again we have found all the topographical elements which combine to shape the western half of our continent. They also appear in the surveys of the most northerly of the United States roads, the Great Northern, but they are no longer recognizable in the profile of the Canadian Pacific.

11. The Great Northern Railway.

The Great Northern railway, like the Southern Pacific, has grown to its present important position by normal expansion from a local to a transcontinental road; and, like the Southern Pacific, it owes its rapid construction and successful management to individual enterprise and high technical skill. During the recent financial crisis neither of these roads passed into the hands of a receiver.

The Great Northern is the descendant of the St. Paul, Minneapolis and Manitoba, a road which was built to tap the Red River of the North. After its reorganization it was extended through Northern Dakota into Manitoba, while still retaining its original designation. Not till it left the valley of the Missouri and attained the dignity of a transcontinental road did it assume its present more appropriate title.

The road keeps to the north over the level prairies of Minnesota and North Dakota, and enters the valley of the Missouri at Willisden. It follows the river to its junction with its large tributary, the Milk, whose valley it utilizes to circumvent the Bear Paw mountains, rather than follow the Missouri in its great bend to the south.

The main line runs almost due west, after escaping from the obstruction which the mountains oppose to its straight path. At the northwestern corner of the Bear Paw mountains, at Pacific Junction, the main line originally turned southwest, rejoined the Missouri at Marian, and followed that river to the Great Falls. There it united with the Montana Central, which continued in the Missouri valley to Helena, whence it crosses the Main divide to reach Butte, Anaconda, and other important mining towns. These lie in an extraordinarily rich valley, between the two forks of the Rockies, the main watershed and the more imposing Bitter Root mountains.

When it was determined to make Puget Sound the terminus,

the main line continued west from Pacific Junction. An easy route was discovered through Snake Head mountains, which alone afforded any engineering difficulties until the main range had to be passed. This it surmounted at Summit (elevation 5202), and it threaded the apparently inextricable labyrinth of hills to the west of the main divide by following the windings of Missoula creek and the Kootenay river, the latter a large, roaring stream, whose banks and enclosing hills are heavily timbered, and which therefore bestows on the scenery a charm not possessed by any of the roads to the south. The Great Northern then turns southward towards Spokane and traverses the head of the great valley, here tapering towards its extinction. At Spokane it connects with and controls an important feeder from British Columbia, the Spokane and Northern R. R. After crossing the Cascade range, at an elevation of 3375 feet, it runs down its western slope to a town of its own creation, Everett, on Puget Sound.

12. The Canadian Pacific Railroad.

The building of the Canadian Pacific was even more a political necessity than the building of the Union Pacific. It followed as a consequence on the admission of British Columbia to the Dominion; nay, rather, it was the price offered to British Columbia as an inducement to join the sisterhood of federated provinces. The surveys were commenced in 1871, and work was begun and languidly prosecuted for years, chiefly in the prairie districts, until the present company was organized in 1880, when construction was pressed with such energy that the track was completed from end to end in 1884. The company now owns and operates a continuous line from sea to sea, and thus divides with the Southern Pacific the advantage of operating a perfectly independent road from tide-water on the Atlantic to tide-water on the Pacific.

The line from Montreal to Vancouver divides itself naturally into three main sections, distinct in their geographical features.

a. The First Section.—This section follows for part of the way the old [illegible] route from Montreal to Georgian Bay up the Ottawa and the Mattawan and along Lake Nipissing. Thence it cuts across country to Lake Huron, and skirts the north

shore of that lake and of Lake Superior, running between Lakes Superior and Nipigon to Port Arthur and Fort William, on Thunder Bay, Lake Superior.

This whole region, from the Ottawa to Fort William, a tract of 670 miles in length, with a width of 300 miles between the lakes and Hudson Bay, covering therefore an area of 200,000 square miles, is to all intents and purposes unexplored. The cold is not more excessive than in the province of Quebec, and the snow-fall is less, but most of the land is unfit for settlement, and there seem to be no such pine forests (unless perhaps in the valley of the Spanish river) as give immediate available value to the valleys of the St. Maurice, the Ottawa, and its eastern tributaries. But it is intersected at distances of about 25 miles by large and rapid rivers, along whose valleys, as well as among the labyrinth of lakes which occupy the Height of Land to the north of the Rocky river of Lake Superior, there are extensive areas of land peculiarly fertile in grasses and roots. The famous Sudbury copper- and nickel-mines give a forecast of the minerals which will be discovered in the Azoic and Palæozoic rocks that underlie the whole of this vast region, which the Canadian Pacific has opened up on the eastern slope of the continent—a region larger than the whole of New England, New York, Pennsylvania, Virginia and Ohio.

The real motive, however, for building this section was the military and political necessity of railroad communication between the members of the Confederation within Canadian territory. As it is, the Canadian Pacific has built an alternative road *via* the Sault Ste. Marie, to connect with roads south of Lake Superior.

The mention of Lake Nipigon recalls the doings of one of the paladins of northwestern exploration, whose exploits have been strangely overlooked in our day. In 1731 Varenne de la Verandraye was commandant of the French fort of Lake Nipigon, and heard the stories of Lake Winnipeg and the country beyond which the Jesuit Fathers, who ministered at the Mission of the Holy Spirit on Lake Superior, had recorded in their *Relations* half a century before. They fired him with the true enthusiasm of adventure; and, aided by a Canadian commercial house and permission from the French crown, he spent the remainder of his life in exploring the routes of the

Northern and Canadian Pacific railroads, more than half a century before Lewis and Clark's day. He ascended the Missouri to the Rocky mountains, but did not cross them. Subsequently he explored the Assiniboine and Saskatchewan, dying almost on the summit of the Rockies in 1749, trying to reach the great Bitter Sea which his Indian guides told him was so near.

This northern zone of the continent, though so cold, or rather because so cold, was better known than any toward the south till we reach the Spanish provinces of Mexico and California. The French had tracked it for furs, and they had established in it missions and trading stations. Contemporaneously the Hudson Bay Company was trafficking with the Indians for their furs at posts along the margin of Hudson Bay.

The two Canadian companies of fur traders consolidated in 1805 into the Northwest Company, which had its headquarters at Fort William, and drew its furs from every stream of the great prairies and mountains to the very shores of the Pacific; with it the Hudson Bay Company soon competed for the peltries of the interior. It was to check or share their trade that Astor sent out his expedition to found Astoria, on the Columbia river. I have already mentioned Mackenzie's first recorded trip from sea to sea by way of the Peace river. Frazer, another fur-trader, reached the sea by the river which bears his name. But not only had this section of the continent been explored with sledge and canoe by the fur-traders: in its heart, at the confluence of the Red river with the Assiniboine, Lord Selkirk, recognizing the marvellous fertility of the Manitoba prairies, had taken steps in 1811 to found his unhappy colony.

His views on many social subjects were as much in advance of his generation as were those of Paterson when he founded his ill-fated Darien colony. The times were not ripe. Many concurrent circumstances must combine to insure success in great social movements. The movements create the circumstances, and the circumstances again stimulate and propel the movements. But when they originate in some individual effort, no matter how philanthropically noble or theoretically correct, they generally end in disaster.

b. The Second Section.—From Fort William,* on Thunder Bay, what was for a time the second section of the road follows the valley of the Kaministiquia and Mattawan for 50 miles till it reaches the low water-shed between Lake Superior and Hudson Bay, not far from where this Laurentian ridge, throwing off a spur, deflects its waters, some to the great lakes, some to the Arctic Sea, and some to the Gulf of Mexico. From this point, for 400 miles, till the Red river is approached, the road skirts a chain of these numberless lakes, which here contend with the amphibious land for complete dominion. It is strange in this far northern clime to find vegetation growing so rank as to build up land in the water. Yet the *muskeg* or *sinkhole* of these vast swamps is the outgrowth of such floating islands as surprised the Spaniards in the Lake of Tezcuco, and so seriously obstruct the navigation of the upper Nile. Here they seem to be solid land till the railway-builder commences to weight them down with his embankment, when their hollowness becomes apparent. At Barclay, the road crossed a *muskeg* beneath which, it was estimated, from the amount of filling required, that there must have been a cavity 200 feet deep. It is unnecessary to point out through what a different climate and country the road passes from that traversed by its southern rivals. The lake-region, it is true, commences within the confines of the Northern Pacific. There the lake offers an agreeable diversion from the land; here the land unfortunately has to be looked for as a diversion from the water. Farther south, the land languishes for want of moisture; here it is drowned by a surfeit of water.

c. The Third Section.—Happily, in the third section, the prairie-division, the balance between land and water, rainfall and drought, is better maintained than in any prairie-region of the whole west; and were it not for the great cold of the winter months, and the early August frosts, the fertile belt of the provinces of Manitoba, Assiniboia and Alberta, for 800 miles westward from Winnipeg to Calgary, would claim undisputed pre-eminence in value as farming and grazing land over the

* An opposition road is being built from Fort William to Winnipeg; it will run much nearer the United States line, and traverse the northern extension of the Mesabi range, in which indications of great iron wealth have been discovered, and give access to the Shebandowan gold-fields.

regions tributary to any of the southern roads. The remarkable leniency of the climate along the base of the Northern Rockies, even as far north as Lake Athabasca, has always been a matter of surprise, and is more or less a meteorological puzzle. It is, however, a fruitful fact to the Canadian Pacific.

From the rim of Lake Superior to the Red river, near its discharge into Lake Winnipeg, it will be seen from the profile with what a regular down-grade the road follows the water-highway. From Winnipeg west it ascends the valleys of the Assiniboine and Saskatchewan. The country traversed rises by three steppes: that of the Red river, with an elevation of 800 feet, through that of the Qu'Appelle district, whose elevation is 1600 feet, to the Calgary plateau, with an average altitude of 3000 feet. At Morleyville the foot-hills are reached, and at Radnor, 904 miles from Winnipeg, the main range is entered through the Bow river pass. The ascent thence is easy to the summit, where at 960 miles from Winnipeg, from twin lakes nestling in a valley four miles wide, two streams flow, one to the Atlantic, another to the Pacific. The mountains rise formidably on each side of the valley, but the divide is passed by grades which, except for the upper five miles of the Bow river, where they attain 116 feet to the mile, nowhere exceed 40 feet. Thus the Rocky mountains are crossed at an elevation of 5300 feet, through a grassy vale, with glacier-clad mountains towering from 5000 to 6000 feet on either side, displaying all the sublimity in height and ruggedness of the Colorado mountains, in contrast with forest and verdure more suggestive of Alpine scenery than anything else upon the continent. Down the west-bound stream the track follows the Kicking-Horse river for 47 miles, to the Columbia, here flowing in a broad stream to the northwest. Down the Columbia river it descends, though here this glorious stream, which begins with a width of a mile, is rather a long, sinuous lake than a river. The Selkirk range lies coastward, and over it the road now passes by the aid of the Beaver river valley at an elevation of 4300 feet, to again meet and cross the Columbia, now flowing southwest. The grades in descending from the main range into the valley where the Columbia is first crossed, in ascending the Selkirk range, and in again descending by the Ille-Cille-Wact into the Columbia valley, to cross it by the

second bridge, are, for short distances, 116 feet to the mile. Another range, the Gold range, has still to be crossed, by the Eagle pass, the three ranges following like waves of decreasing volume. Westward of the Gold range the road enters the valley of the South Thompson, and skirts the banks of the Shuswap lake (with one leap over an obstructing promontory) and the South Thompson river to Kamloops, where the North and South Thompson unite and discharge their streams into Kamloops lake.

From Kamloops the road follows the lake, and the Thompson, and finally the Frazer river, through the gorge which it has cut through the Cascade range. At the mouth of the gorge is Yale, and fifteen miles below is Hope.

Below Yale the waters become tamer, and at Hope they are navigable for river-boats to Westminster, a port of capacity sufficient for the largest ships. Twenty-six miles from Port Hammond, where the railroad leaves the Frazer river, is Vancouver, the terminus of the road.

To identify the geographical features of the section is more or less guesswork. The first and highest range crossed is undoubtedly the Rockies. The last range, not crossed by the railway, but penetrated by the gorge of the Frazer, is generally identified with the southern Coast range. It more correctly corresponds, I think, to the prolongation of the Sierra Nevada, the Gulf of Georgia occupying the coast-valley, and the Coast range surviving in the island of Vancouver and the Queen Charlotte group. The intermediate ranges, the Selkirk and the Gold, are probably homologous with the Wasatch and Humboldt; but the crushing together of the whole mountain system has obliterated the great valleys; and the change in climate, resulting in the creation of numerous large and impetuous rivers, has introduced eroding, modifying influences, not so appreciably felt in the configuration of the southern mountain- and valley-system. From the base of the Rockies at Cheyenne, on the Union Pacific, to the foot of the Sierra Nevada at Colfax is 885 miles. On the Northern Pacific route, about 500 miles north of the Central Pacific, between corresponding points, the mountain system is 590 miles wide; whereas from the base of the Rockies here to what we may assume to be the base of the Sierra chain is only 330 miles.

The scenery of the mountains in this parallel is modified not only by these geographical variations but by the heavy clothing of forest-trees. Unhappily these features will rapidly disappear, for it is no more in the nature of a Canadian than of a Californian to plant for posterity a sapling to replace the tree he cuts down. One effect of the thick covering of soil and timber interests mining engineers. It seriously interferes with and retards prospecting for minerals. The arbitrary line between the United States and the British provinces, as has been proved in the Kootenay region, does not limit the deposits of valuable minerals. But they will be more gradually discovered, and less rapidly exhausted, than our own.

III.—STATISTICS AND CONCLUSIONS.

This rapid sketch may be appropriately supplemented by tables of distances, and other statistics.

Union and Central Pacific.

	Miles.
San Francisco to Omaha,	1867
Omaha to New York,	1412
	3279

Southern Pacific.

San Francisco to New Orleans,	2476
New Orleans to New York, by rail,	1373
	3849
San Francisco to Galveston,	2133
San Pedro (port of Los Angeles) to New Orleans,	2021
San Pedro to Galveston,	1678

Atchison, Topeka and Santa Fé.

San Diego to Chicago,	2347
Chicago to New York,	912
	3259
San Diego to Galveston,	2437

Northern Pacific.

Seattle to St. Paul,	1923
St. Paul to New York,	1320
	3243
Seattle to Duluth,	1939

Great Northern.

	Miles.
Everett to St. Paul,	1790
St. Paul to New York,	1320
	3110
Everett to West Superior,	1849

Canadian Pacific.

Vancouver to Montreal,	2906
Montreal to St. John, N. B.,	481
	3387
Vancouver to Port Arthur,	1913

The Southern Pacific port of San Pedro, from which to Galveston is by far the shortest transcontinental railroad-distance, is not available for ships of large tonnage, and San Diego, the Pacific terminus of the Santa Fé's own line, by no means possesses the capacity or the trade of San Francisco. The Santa Fé is building across the great plains of Central New Mexico and Texas to connect Albuquerque with its gulf line, which connection will shorten the distance from sea to sea, and escape the heavy grades of the Glorieta and Raton ranges; but the unfavorable location, as shown by our profile map, of the Santa Fé Pacific, places the road at a disadvantage as compared with the Southern Pacific. The comparison of distances from sea to sea is in favor of the Southern Pacific, but the comparison of profiles somewhat favors the northern roads. The advantages which fit them to be economical freight-haulers lie, therefore, between the northern roads and the most southerly of the six competitors. Climate is, however, an important factor when we are judging of the commercial value of each route. Cold and the snowfall are influenced by altitude even more than by latitude. The Canadian and the Central in this respect stand almost on a par.

The road most favorably situated as regards climate is the Southern; but the semi-tropical rains of Southern California and Texas are at times as obstructive to traffic as the snows of the north. No road, therefore, can claim such geographical superiority over its rivals as to give it supreme advantage, and therefore relieve it from the necessity of maintaining a conciliatory attitude towards its competitors and its customers.

The total mileage, owned and operated by the great roads we have described, is as follows:

Total Mileage of Transcontinental Railroads.

		Miles.
Union Pacific,	2,985 miles	
Kansas Pacific,	746 "	4,272
Oregon Short Line,	541 "	
Southern Pacific Co.,		5,414
Atchison, Topeka and Santa Fé, including Gulf, Colorado and Santa Fè, Southern California, and Santa Fé Pacific,		6,946
Northern Pacific,		4,527
Great Northern,		4,698
Canadian Pacific,		6,547
Oregon R. R. and Navigation Co.,		1,059
Denver and Rio Grande,	1,648 miles	
Rio Grande Western,	550 "	2,533
Colorado Midland,	335 "	
Total,		35,996

The Denver and Rio Grande and its colleague roads, which have no outlet on the Pacific, have really no more right to be classed as transcontinental than the Chicago and Northwestern and other western roads which are creeping across the Rockies; but the influence of this famous narrow-gauge on the economical progress of Colorado entitles it to a position which none of the newer competitors for the traffic of the mountains can claim.

The amount of railroad capital represented by the transcontinental railroads under consideration reaches the stupendous figure of more than $1,700,000,000, distributed as shown in table on page 817.

Large as it is, this figure is calculable; but the influence of the roads on the political, social and economic history of the whole nation has been incalculably great. What more immediately interests us is, of course, the aid they have afforded to mining and metallurgy.

The influence of the railroads on mining has not been more important than the reciprocal influence which the mining industry has exerted on the railroads. The first interests to receive a stimulus were the lead-mines of Utah and Nevada, on the completion of the Union and Central Pacific railroads. Shipments of the richer argentiferous lead-ores preceded smelt-

Capital and Funded Debts of the Transcontinental Lines.

(Statistics as of July, 1899.)

	Common Stock.	Preferred Stock.	Funded Debt.	Total.
Union P. . . " "	[illegible]	$75,000,000	$91,000,000	$253,585,400
North. " " †	80,000,000	75,000,000	158,801,000	313,801,000
South. " "	198,464,494	....	117,917,000	316,381,494
Canad. " "	65,000,000	20,951,000	116,759,999 £ 10,350,373	202,710,999 £ 10,350,373
Gr. N. " "	....	89,876,900	$ 82,866,990 £ 3,000,000	$172,743,890 £ 3,000,000
At., T. & S. Fé. "	102,000,000	114,199,500	$180,694,210	$396,893,710
				$1,656,116,493 £ 13,350,373

ing up to the years 1872 and 1873, even as the shipments of the richer copper-ores of Montana were made in advance of the advent of the Utah and Northern railroad into Butte. But not until the metallurgist came to the assistance of the miner, and the railroads supplied moderately cheap fuel, did the West become the controlling factor in the production of copper and silver which she is to-day in the market of the world.

The beginnings of gold- and silver-mining in the Eastern range of Colorado antedate the arrival of the railroad; but only when the Union Pacific system reached Denver could the sulphurets of Gilpin county be smelted into mattes, or the refractory ores of Clear Creek county be advantageously treated. At first Senator Hill, at his furnaces in Black Hawk, used wood as fuel; but the necessity of coal for metallurgical treatment and for railway service became so urgent as to encourage the opening up of the coal-fields in the Eastern range of the Colorado Rockies. For a time Senator Hill shipped his mattes to England for separation; but a step in the direction of home treatment, like those which have marked the progress of both lead- and copper-smelting in the West, was taken when our ex-President, Richard Pearce, introduced the Ziervogel method for the treatment of gold-bottoms, with modifications, into the works of the Boston and Colorado Co.

* The authorized bond-issue is $100,000,000, but only outstanding $91,000,000.

† The authorized bond-issue is $320,000,000, but only outstanding $158,801,000.

The discovery of Leadville and the active development of both mining and metallurgy in that direction were the most potent agents in stimulating railroad-building, the exploitation of coal-mines, and the manufacture of coke in Colorado. There alone in the West, moreover, coexist iron-ore, coke, and a market large enough to warrant the manufacture of iron and steel—an industry which everywhere has important reflex influence on railroad building and railroad prosperity. The raw material of iron-manufacture is by no means confined to Colorado. The iron-ore deposits of Silver City, New Mexico, are both extensive and rich, but conditions are not yet favorable for the active economical development of these and other similar iron-ore bodies. There is coal in central and southern New Mexico, but the beds are so fractured and faulted as to have made mining heretofore less profitable than on the regular coal-beds of the Raton range, both in Colorado and New Mexico. These afford the most available supply of fuel for both the locomotives and the furnaces of the southwest. The statistics of 1898 give the product of bituminous coal in Colorado as 4,125,206 tons; of coke in Colorado as 445,925 tons; and of coal in New Mexico as 863,583 tons. The Wyoming coal-mines are credited with 3,181,905 tons. Montana's coal-production has reached 1,450,471 tons, and the coal is of a quality which relieves the smelters from drawing any longer a notable supply from the Canadian northwest. Washington, even, contributes over 1,988,288 tons to the ever-growing demand. Thus these western coal-areas, so recently opened, contribute nearly 12,000,000 tons, or about 7 per cent. of the country's total production of bituminous coal.*

Copper has been, after coal, the most essential auxiliary of all of the mining products to the Western railroads. Its bulk and the large proportion of fuel consumed in the reduction of its ores have made it one of the most valuable items of western freight. At the same time the copper-industry owes its origin and growth entirely to transportation facilities.

Though the Longfellow mine in Arizona smelted small

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* Taken from Rothwell's *Mineral Industry*, vol. vii. (1898), pages 161 and 162. The tons are short tons of 2000 pounds avoirdupois.

quantities of ore with vegetable fuel, and shipped small quantities of copper for 700 miles to the nearest railroad-station on teams which had brought merchandise into the valley of the Rio Grande, only the exceptionally high price of copper in the '70's permitted this. It was not until the Southern Pacific from the West, and the Atchison, Topeka and Santa Fé from the North, made a junction at Deming, that the Bisbee, Clifton and Globe districts became notable producers. So also, though small quantities of rich argentiferous ores were shipped from Butte to Corinne, on the Central Pacific, before the Utah and Northern was built, Butte did not rise into prominence as a copper-producer until that road had reached Silver Bow county in Montana. Now, the copper-industry of Montana must supply the railroads directly with about one million tons of long-haul freight in and out, and about two million tons of short-haul freight; and the Arizona copper-industry gives them about half a million tons of long-haul freight. If the trade of the Pacific were always to be from west to east, there would be a superfluity of transportation-facilities; but the current is sure to turn, and ere long there will be a heavy freight-traffic to Pacific ports. It is not reasonable, to take a single instance, that our western copper should continue to be shipped from the middle West to the East and Europe, there to be manufactured into specialized shapes and sold to the Orient as India sheets, or in any other form. Coal, skill, transportation and shipping-ports are ready to our hand, and the western miner and metallurgist will ere long become a manufacturer, under the influence of these beneficent harmonizers of sectional interests—coal and railroads.

As we are a country of great distances, this is especially true. If coal were not widely disseminated, and fuel for our locomotives had to be hauled a thousand miles or more, our freight charges could not be, as they are to-day, the lowest in the world. And if coal were confined to a few and distant regions, manufacturing could never have become, as it has done, a common occupation of every section of the land; but the West would still be a grain-producer, the South a cotton-grower, and the metal and manufacturing interests would be confined to the Middle and North Atlantic States. As it is, thanks to the abundance of coal in Illinois, Chicago and other

towns in that State are as conspicuous for their steel and other manufactures as Pennsylvania itself. The "New South," with its great coal-resources in the Virginias, Tennessee and Alabama, is to-day fixing for the older iron states the price of pig-iron and is converting into textile fabrics her cotton in her own factories. This interfusion of manufacturing and farming is effectually correcting the old subdivision of the country into communities of opposing interests, and therefore of conflicting prejudices. Even what was till recently the "Far West" is entering the community of manufacturing states, owing to the possession of coal. Not only do coal and prosperity go hand in hand, but coal and politics are close allies.

It was the discovery of gold in California, and the rush thither to reap a golden harvest without sowing any seed, which stimulated the peopling of the west coast; and it was the Mormon exodus from Illinois, the very same year, and the conversion, by these religious fanatics, of a tract of country in the very heart of the great desert into an oasis of beauty and fertility, which proved that the mountains would yield other products than the precious metals. Miners and Mormons were, therefore, the elementary material out of which western life was originally composed.

While other elements have since been introduced, mining and ranching are still its staple industries, but both are pushed with an energy and intelligence beyond comparison. Western fruit, western wheat, western cattle, are feeding the world. For the rate of discovery and recovery of the precious metals, we have to look back to the years following the Spanish conquest of the continent, to find a parallel. The Pacific railroads have, to all intents and purposes, doubled the area of this country and Canada, and they have done it in the short period of thirty years. A region 1000 miles wide by 2000 long, rich in minerals, and utterly virgin ground, was scoured. It is practically bare of soil and unconcealed by forest, and therefore exploration has been easy and discovery rapid; but hardly more rapid than the avidity with which the discoveries, once made, have been utilized.

The statistics of the precious metals mined since 1849 afford proof of this. Between that date and 1898 the Rocky mountains yielded about $4,500,000,000 in gold and silver. The

Comstock lode alone produced from 1860 to 1880 $306,000,000 in gold and silver.

It is worthy of note that on the construction and equipment of the whole 40,000 odd miles of railroad in the Rocky mountain system there has been spent more than one-third the total production of the precious metals.

Despite the relatively small value of copper, its mining and reduction have been pursued with the same haste, a haste which, in this case as in that of the precious metals, has necessarily involved a heavy waste. The great copper-mines and smelting-plants designed on such a stupendous scale have been the controlling factors in the world's copper-market for the last twenty years. The quantity of copper they have turned out has been approximately 3,500,000,000 pounds.

But the men themselves have had almost as powerful an influence on the world's history as the production of their hands and brains has had on the world's markets. The isolated outdoor life passed by the herdsmen, prospectors, miners and ranchers of the Rocky mountains and the Pacific slope, far from the restraints of society, has created a race which acts under very different impulses from those which kept the New England and Virginia colonists content with their narrow home between the Atlantic and the Alleghenies. And the self-assertive, though generous, spirit of the pioneer, who is untrammelled by precedent or prejudice, has communicated itself to the mercantile and technical classes of the West, and thus has helped, not a little, in fostering its extraordinary rapid growth. These men of the West are the real *coureurs de bois* of our day, and Acts of Congress would be as powerless to restrain them as were the *édits et ordonnances* of the French governors to check the roving habits of their predecessors. Wherever there is a new country to explore, if it contains minerals, these are the men to explore it. Let there be a great gold discovery in arctic or tropic regions, in the Klondike, or in central Africa or New Guinea, and a contingent will start from the Rockies by the earliest train to catch the first steamer, with no baggage but its blankets—and the expedition will reach its goal, wherever that may be.

After this imperfect survey of what has been done since 1862 in railroad-building west of the Missouri, and in the pioneer

industries which have followed close upon the locomotive, founding a new empire on the Pacific slope, I think that, whether or not the proposition be accepted, with which I began, that our worthy ancestors on the Atlantic coast were somewhat lacking in the spirit of adventure, it must be allowed that our eastern contemporaries are not deficient in courage and enterprise.

We can heartily adopt the words of our Secretary,* with which I may appropriately close this chapter.

"To me, who count myself still a young man, it is a perpetual marvel that, in my professional career of less than thirty years, I have witnessed the successive stages of this unparalleled growth. I have seen the pioneer mining camps in every State and Territory to the shores of the Pacific. The cabins of the miners among the pines and snows; the slow ox-teams upon the alkaline desert; the laden 'burros' on the rocky trails; the long days in the saddle; the quiet camping under the stars; the faces of savage foes, and the fight or the ride for life—they are all known to me; and out of these rude beginnings I have seen an empire spring.

"Yes, Nature lay, beautiful and rich, a sleeping princess, wrapped in the spell of silent centuries. And behold! at the kiss of the American engineer she stirred; she woke; she smiled; she recognized her lover and master; she gave herself to him, in all the radiance of her beauty, in all the splendor of her dower! It is indeed the fairy-tale of history; and the part of the fortunate prince has been played in it by the profession to which we are proud to belong. The arts of the miner and the metallurgist have led the way in this amazing advance, building railroads and cities, and attracting and supporting all allied arts and industries. The like will not happen again. There are no more *such* worlds to conquer. To have seen it—to have been a part of it—what greater glory can a man desire?"

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* Speech of Dr. R. W. Raymond at the banquet of the Iron and Steel Institute, New York, October 2, 1890.

Glacial Erosion and the Origin of the Yosemite Valley.

BY WILLIAM P. BLAKE, TUCSON, ARIZONA.

(California Meeting, September, 1899.)

THE visit of members of the Institute to the Yosemite valley, in connection with this meeting, suggests a short discussion of the relations of glaciers to mining; of the origin of the gorge of the Yosemite; and of sub-glacial erosion generally.

MINING ACTION OF GLACIERS.

It is scarcely necessary to point out the important functions of water in the mining operations of man, especially in the State of California, where sluicing and hydraulic mining have been practiced on such a grand scale as to arouse the opposition of the agricultural interests. But the *rôle* which water and ice have played in mining or excavating on their own account is not so apparent. The alluvions of existing rivers, and the higher gravel-beds left by ancient streams, are doubtless the result of running water; but how far these gravelly materials owe their origin primarily as rocky *débris* and fragments of veins to glacial erosion, it is difficult to determine. Yet we see on every side in our higher mountains unmistakable evidences of the cutting, crushing and eroding effects of glacial ice. We note that mountain-summits have been reduced in height and shaped into rounded and dome-like summits. We know that the general contour of the hills of New England, of the Highlands of the Hudson, and of the mountains of northern New Jersey, is due to glacial carving. The same is true of the Laurentian hills of Canada and of the mountains of all northern regions. And we recognize in the vast deposits of so-called "drift," which are spread out over the surface of the northern States, the chips and *débris* from the glacial workshops. Thus we cannot avoid the conclusion that there was an enormous amount of cutting and excavating in glacial times, and that vast quantities of vein-material and of ores and metals must have been liberated by ice-action.

This fact is made more evident to us, as miners, by the fact that in the banks of glacial *débris*, brought down as moraines from the copper-region of Lake Superior, we now and then pick up masses of native copper, which have been torn from their original matrix in the veins. In like manner, masses of copper from unknown veins have been found in Hamden, Connecticut. Only recently, an eleven-pound mass was dug up on Mill Rock, Conn., in the midst of a sub-glacial moraine. It was battered, rubbed and folded upon itself in such a way as to show the immense rolling pressure to which it had been subjected between the glacial *débris* and the bed-rock.

The discovery of good diamonds in the old glacial moraines of Wisconsin* shows that there is, somewhere to the northward and in the path of the old glaciers, a source of this gem; and this discovery has stimulated a systematic search for that source. Late researches by Bonney have shown that, in some, at least, of the more important deposits of diamonds, the gems have been torn by some cyclopean force from their original home; and this force was probably exerted by ice.

Northern New Jersey and the iron-ore regions of the Adirondacks show the part which the ancient glaciers played in mining and distributing iron-ore from its beds in the Archean rocks. The beds themselves bear the records of the passage of the glaciers, and its direction, over their outcropping edges.

The zinc-ore and franklinite-beds of Sussex county, New Jersey, afford a striking example of what may be termed *glacial mining.* I have elsewhere† directed attention to the fact that hundreds, perhaps thousands, of feet of ore-croppings have been broken off, crushed, rounded and distributed in the path of the glacier to the southward. Ore so broken out and accumulated was for many years one source of supply for an American zinc-works. One mass of such ore was so large that it was mistaken for the cropping of a bed in place. Hundreds of tons were taken from it. Other examples might be given; but these are sufficient to indicate that glacial ice has contributed in no small degree to the breaking-down of mineral veins, and to the distribution of ores and minerals.

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* See the interesting paper of Mr. Wm. H. Hobbs, "The Diamond Field of the Great Lakes."—*Jour. Geol.*, vii., 375, June, 1899.

† *Trans.*, xxiv., 523.

The miner is not alone in indebtedness to glacial erosion. The farmer must recognize the agency of ice in providing disintegrated rock as a basis of arable soil. Shaler* has pointed out the immense service performed by glaciers in breaking down and transporting rock-fragments from the north to the south, giving to the Northern and Middle States a supply of materials for making roads.

Enormous Glaciation in California.

In no portion of the United States can we find the phenomena of former glacial action on so grand a scale as in California, in the central portion of the Sierra Nevada, at the sources of the Tuolumne, the Merced and the San Joaquin. This is the broad elevated region above the gorge of the Yosemite, on the Merced. That gorge, grand and impressive as it is, is but one of the minor features of the vast glaciated region above it, extending for hundreds of square miles to and beyond the summit of the range, which here culminates in a succession of peaks, from 10,000 to 14,000 feet, or more, in height. In this alpine region of the United States, the records of former glaciers are more magnificently impressed upon the mountains than in Switzerland. Not even the *moutonné* region of the Grimsel compares in extent and grandeur with that of the upper Tuolumne, in the Sierra Nevada.

In traversing the Sierra from the Yosemite to Lake Mono, by the high trail to the eastern side of the divide, we cross a glaciated region some 30 or 40 miles wide; and we are surrounded by glaciated summits, grandly carved and shaped by glacial ice armed with sub-glacial moraines. Figs. 1 and 2, the former from a photograph, the latter from a pen-drawing, exhibit these rounded summits.

The rock is generally a compact gray granite, containing large crystals of feldspar, often three or four inches in length, forming a coarse granitic porphyry. But some of the higher peaks, notably Mt. Dana, Mt. Gibbs and Mt. Hunt, are, in part, metamorphic slate and red sandstone. The glaciated floor is everywhere smoothed, and even polished, to such a degree, in places, as to reflect the sunlight like a mirror. In the steeper cañons on the eastern declivity, leading down to the Great

* N. S. Shaler, *Report U. S. Geol. Survey*, xv., 1893-94, p. 275.

Basin region, the smoothness and polish of the rocks make the paths dangerous for animals, and have earned for the Mono trail route the title of "Bloody cañon."

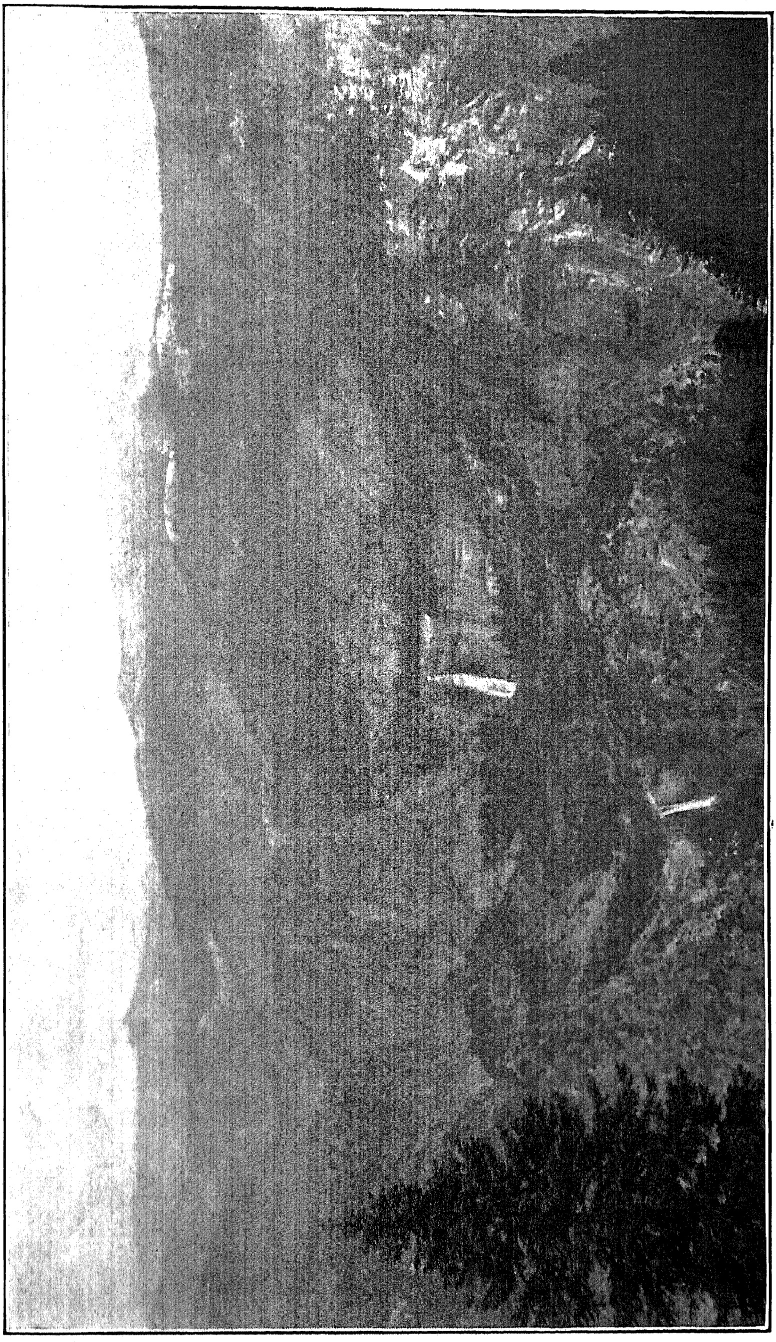
The glaciation of this upper region appears to have been effected by an ice-sheet nearly, or quite, 2000 feet thick. Its effects are visible up to the altitude of at least 11,000 feet, nearly to the summit of Mt. Dana (13,225 feet); and, below that, to the top of the Yosemite walls (about 8000 feet in altitude). But this is not all. The ice has left its records *in* the Yosemite, even to the floor of the valley. If we assume a thickness of only 1000 feet of ice above the walls of the valley, the ice must have been 5000 feet thick; but if only half of the gorge was filled by the ice, the pressure on the floor must have been enormous—not less than 120,000 pounds to the square foot of surface.

Imagine, then, a glacier, moving over the rocky floor of the gorge—a plastic mass, holding firmly imbedded in its bottom surface a mass of broken rocks, like so many planing tools, moved forward irresistibly, one following another over the granite for untold ages; these rock-masses being held firmly to their work, like diamonds in a rock-drill, under a pressure of 60 tons to the square foot! The result could not fail to be extensive abrasion, erosion, cutting and shaping.

Some years ago, many distinguished geologists doubted the agency of glaciers in cutting, carving and shaping mountain-masses, and especially their agency in cutting deep valleys. Perhaps there may be, to-day, some geologists and engineers who still have doubts on this question. To all such, I would commend a week's study of the region above the Yosemite, or of any glaciated region such as many members of the Institute recently passed through on their journey up the Hudson, and in Montana, Idaho and Oregon.

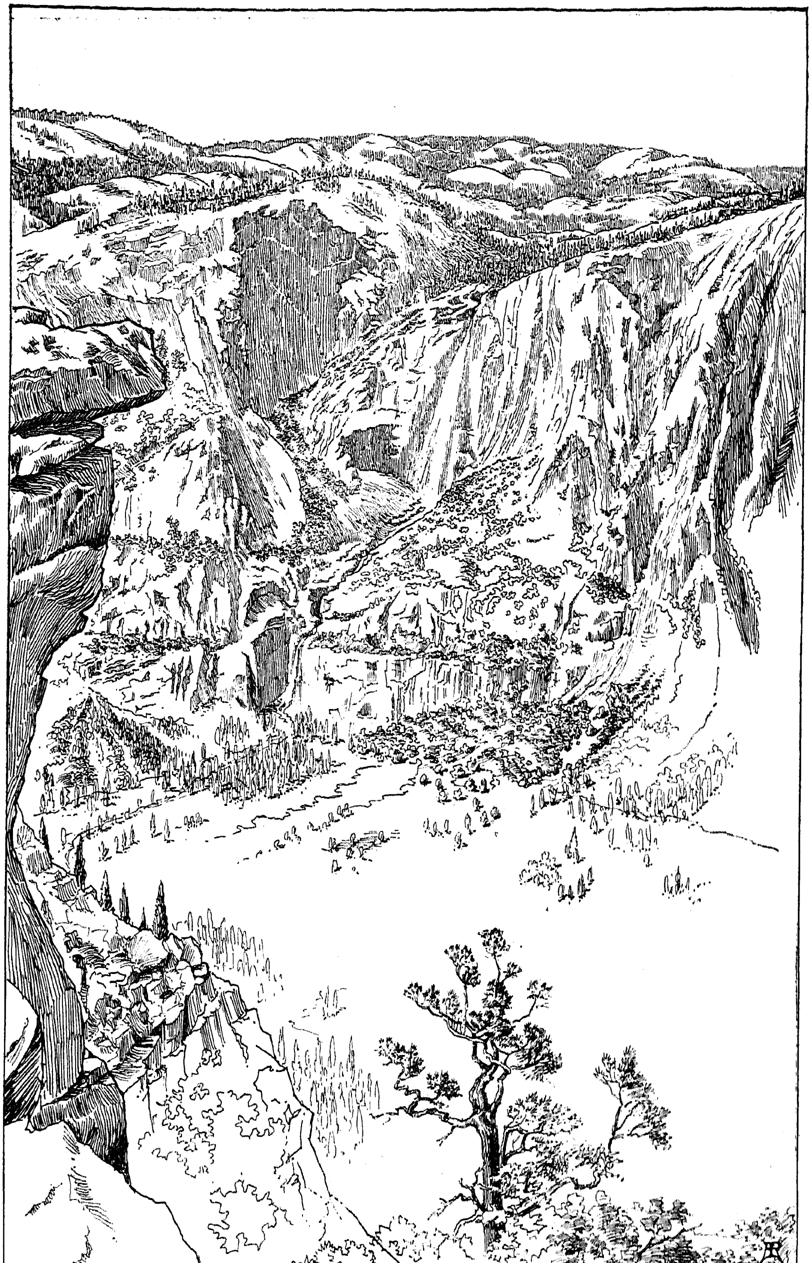
ORIGIN OF THE YOSEMITE.

Having been greatly impressed, on my first trip to the Yosemite, in 1866, by the evidences of enormous glaciation in and around that valley, and stimulated by the beautiful photographs sent by Mr. C. E. Watkins to the Paris Exposition in 1867, I read a paper before the French Academy of Sciences, in Paris, upon the former existence of glaciers in the Sierra Nevada and



View of the Vernal and Nevada Falls, and of the Glaciated Region Above, Taken from Glacier Point.

FIG. 2.



Pen-Sketch from Photograph, Showing Yosemite Falls and Glaciated Rocks Above. Taken from Glacier Point.

the origin of the Yosemite Valley.* In that paper I explained the origin of the valley on the theory of sub-glacial erosion; but, deferring to the prevailing view of erosion by water, rather than by ice, I gave to the supposed under-flowing water greater prominence in producing the result than I would give to-day.

This glacial explanation of the origin of the Yosemite was not favorably received by Prof. Whitney, then State Geologist of California, who declared that aqueous erosion could not possibly be the cause, and that "much less can it be supposed that the peculiar form of the Yosemite is due to the erosive action of ice." . . . "A more absurd theory was never advanced than that by which it was sought to ascribe to glaciers the sawing out of those vertical walls and the rounding of the domes."†

Prof. Whitney's theory was, that, owing to some great convulsion or uplift, a block of rock, corresponding to the form of the main Yosemite valley, had dropped down, thus leaving a profound cavity which had since been partially filled with the *detritus* of the streams, forming the approximately level floor of the valley, as we find it to-day.

In this discussion of the origin of the Yosemite, we must not lose sight of the fact that there is a second gorge or valley, closely simulating the Yosemite, and situated several miles northward, known as the Hetch-Hetchy. It is on the Tuolumne drainage-system, and in the line of prolongation of the ancient Tuolumne glacier, known to have had a length of about forty miles, and including the ice-field from which the Merced and other glaciers also flowed. We thus find two similar gorges, widely separated, both of them in the line of drainage and both exhibiting in a marked degree the records of glacial action.

One of the chief objections to the glacial theory of the shaping of these valleys is the supposed absence of moraines at the former lower ends, or sides, of the glaciers. I say "supposed," because it is by no means proved that morainic materials do not exist along the lower parts of the Merced valley. Moraines have been found at the south end of the Hetch-Hetchy, at an elevation of fully 1200 feet above the bottom of

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* *Sur l'action des anciens Glaciers dans la Sierra Nevada de Californie et sur l'Origine de la Vallée de Yosemite. Par* W. P. Blake. *Compte Rendus*, 22 Juillet, 1867.

† *The Yosemite Book*, p. 76.

the valley, thus indicating an equal thickness for the glacier at that point. Whitney himself wrote that there was no doubt "that the great glacier originating near Mount Dana and Mount Lyell found its way down the Tuolumne cañon and passed through the Hetch-Hetchy valley. Within the valley the rocks are beautifully polished up to at least 800 feet above the bed of the river. Indeed it is probable that the glacier was much thicker than this."*

This was a concession hardly to be expected from one who refused to believe in the existence of even small glaciers in the Sierra at the present day, and who, I believe, was never willing to concede that the Yosemite, like the Hetch-Hetchy, had been once occupied by a glacier. But of this occupation by ice there is ample evidence.

Clarence King early detected signs of glaciation near the summit of Glacier Point, high above the floor of the valley. From Glacier Point, where especially fine views of the valley below, and of the summits above, may be had, the *moutonné* surfaces may be seen extending as far west as El Capitan and around, and even below, El Capitan. The higher remarkable dome-shaped summits around the valley may not be due wholly to glacial carving; but, taking a general view of the upper region, and realizing that the ice must have covered these domes, it is difficult to except them from the general result. The rounded bosses of granite and the *moutonné* surfaces are well shown in the photographic views of the upper Yosemite.

In a third visit to the Yosemite, in 1887, I gave special attention to the question whether the ice which covered the general surface above had left any traces of its presence below, and found that the bluff nearly opposite the Yosemite Falls, and marked on Wheeler's map as Union Point (altitude, 6290 feet), is glaciated on its nearly vertical sides from top to bottom, and that patches of the wall, here and there, retain the old polished surface. This bluff is lower down the valley than Glacier Point, between that point and the "Sentinel." Standing on the bed of the valley directly alongside this vertical wall, one can see that it is glacier-moulded from top to bottom. The polished surfaces have generally been removed by the frosts of

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* *The Yosemite Book*, p. 99.

ages; but the wave-like carving made by the ice, remains, and gives evidence of the former occupation of the gorge by a glacier from top to bottom.

Existing Glaciers Above the Yosemite.

For the discovery of existing glaciers in the Sierra Nevada we are indebted to John Muir, the accomplished mountaineer and author. At the date of my original paper, glaciers had not been found in California; and their existence, though suspected, was denied.* They are now known to be numerous, but small in size—mere remnants and miniature representatives of the ancient ice-fields which covered the mountains, with the exception of the tops of the loftiest peaks.

Probably the most perfect amongst these existing glaciers is the Dana glacier upon Mt. Dana. It originates in a regular *névé* on the north face of the mountain, near the summit. It then consolidates into true glacier-ice, with all the usual accompaniments of dirt-bands, crevasses and moraines, and finally ends in a small but deep lake (Lake Amy †) of blue water, opalescent with the fine silt from the glacier. Small icebergs are here broken from the end of the glacier and float away.

An excellent description of the glaciated region of the high Sierra has been given by Prof. I. C. Russell, of the U. S. Geological Survey. He directs attention to the existence of *arêtes*, *cirques* and amphitheaters in the surrounding region, especially at the head of the Tuolumne. While he concedes the occupation of the great gorges by ice, he believes that the great valleys were formed before the ice-period, and that the glaciers followed these pre-existing channels. As to the Yosemite, he gives his adherence to Whitney's theory of the subsidence of an orographic block, rather than to the theory of glacial erosion.‡

That the topographic features of the Sierra Nevada were, before the ice-age, substantially the same as now, was claimed

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* When I was traversing the San Joaquin and Tulare valleys of California, in 1853, the sky-outline of the crest of the high Sierra, with its gaps and its sharp peaks, rising above great fields of unbroken snow (*cirques* and amphitheaters), suggested to me the existence of glaciers there. See *Report of a Geological Reconnaissance in California*, p. 26. Also, Volume V. of *Pacific R. R. Exp. and Surveys*.

† So named by me in honor of the daughter of Prof. Jas. D. Dana.

‡ "Quaternary History of Mono Valley, California," *U. S. Geol. Survey*, 8th *Ann. Rep.*, 1886–1887, Part I., p. 269.

by Prof. Whitney, who declared that the glacial epoch in California did not occur until long after the accumulation of gravels had ceased, and the topography of the country had assumed its present form, down, almost, to its minutest details.*

I do not wish to be understood as contending that the topographic features of California are wholly due to ice-action, or that there were not valleys of drainage before the glacial period. No doubt such valleys did exist; and that the direction and paths of drainage were originally determined by inequalities in the surface due to elevation, fracture, cleavages, decomposition and other causes, is not questioned; but the peculiar U-shaped form of the Yosemite valley, its precipitous sides and present configuration, which give to it its grand and unique character, are due, as I claim, to ice-action, and not to river-erosion, or to the subsidence of an orographic block.

The absence of moraines (if, indeed, moraines are absent) may be explained by the consideration that if the ice not only filled the valley but extended each way above it, as seems to have been the case, there was no opportunity for the formation of lateral moraines, while the material of the ground-moraine and the products of its action might be carried away by the sub-glacial stream.

Le Conte has advanced a theory that glaciers ending in a lake or sea may not form terminal moraines. While it cannot be claimed, from present knowledge, that the Yosemite glacier ended at any time in a lake, we must not overlook the fact that in late Tertiary time the Tulare valley was occupied by the sea, and possibly to a height corresponding to the foot of the glacier.

We should also note the fiord-like form of both the Yosemite and the Hetch-Hetchy. They might be called interior fiords.

Structure a Factor in Glacial Erosion.

In all cases of ice-sculpturing and erosion, the resulting form depends largely upon the nature of the material acted upon. In the Yosemite and Tuolumne region we have a homogeneous massive granite, in which, however, there is a vertical structure, or tendency to cleave in nearly vertical planes. This structure

* "Auriferous Gravels," p. 336.

is clearly shown by the weathering of the cliffs at many places in the valley, and in the rocky bluffs or summits contiguous to it, notably in the Cathedral Rocks, the Sentinel, and the bold sides of El Capitan.

This vertical cleavage-structure was an important factor in the formation of the valley, and probably of the *cirques* above it; for it permitted the breaking-down of the rocks in large blocks under the ice, so that the excavating and eroding effect of the glacier was greatly promoted.

In the explanations, hitherto offered, of the mode of action of glaciers upon their rocky beds, undue prominence appears to have been given to the merely abrasive grinding and scoring action of the ground-moraine, to the neglect of the much more rapid and violent effects of splitting, quarrying and crushing the bed-rock, especially when these effects are made possible on a grand scale by structural planes of easy cleavage.

In considering the dynamics of glaciers, then, we must take into account not only the weight of the ice, its motion and the nature of the ground-moraine, but also the structure of the rocks acted upon. Take, for example, a slate formation, such as we find to be beautifully glaciated in the region of Mounts Dana, Gibbs, Hunt* and Conness, with the foliation on edge in vertical planes. The surface is planed down smooth, and shows the usual grooving and polishing; but on reaching a sharp declivity or cliff, a very different condition is found. The slates are boldly and deeply broken over; the smooth even surface is destroyed; and great blocks and sheets of slate are detached and thrown down under the ice. Imagine the glacier, a thousand feet thick or more, moving over such a cliff as indicated diagrammatically in Fig. 3. The erosion in such a case is not confined to the merely abrasive, grinding effects of the ground-moraine, but proceeds rapidly by quarrying rather than by rubbing. This quarrying proceeds backwards under the ice, and may be likened to underhand stoping in mining operations.

I conceive that the erosion of the gorge of the Yosemite and, to a great extent, the form of the valley, were promoted by the

* Mount Hunt is a high, conical mountain, near Mounts Dana and Gibbs, and was so named by me in 1887, in honor of the late Thomas Sterry Hunt, LL.D., F.R.S., for many years a member of the Institute and of world-wide fame as a writer and authority in chemical geology.

vertical structural planes of the granite. In the same way, I would explain the origin of the *cirques* and amphitheatres, which have been a puzzle to geologists. A declivity once formed in a rock having vertical structural planes, the breaking-down proceeds backwards rapidly in step-like shelves, such, in fact, as we find at the Vernal falls and cascades, and higher up under the slopes of the Mount Lyell group.

We may in the same way explain the formation of the peculiar bluffs of trap, which so pleasantly diversify the scenery of the red sandstone region of Connecticut and New Jersey. The escarpments known at New Haven as East Rock and West

FIG. 3.

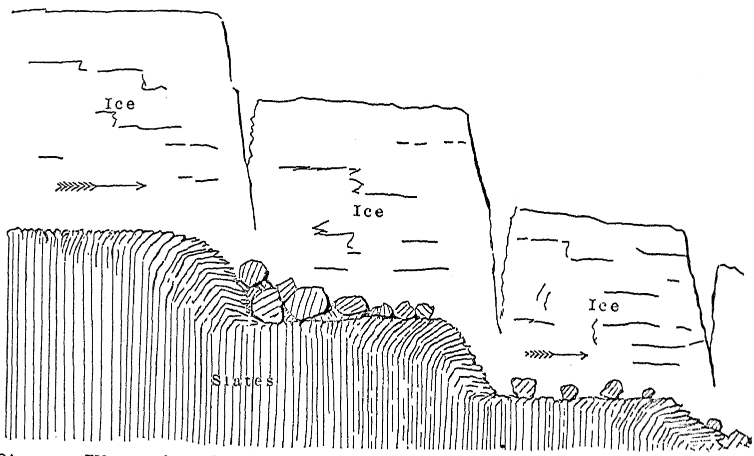


Diagram Illustrating the Effect of Heavy Ice Moving over Cliffs of Vertical Slates.

Rock, and at Meriden as the Hanging Hills, were all evidently at one time laccolites in the sandstone, which assumed a nearly vertical columnar structure. Under the action of the great ice-sheet, the surface was not only abraded, grooved and smoothed, but the trap was broken away in large columnar blocks under the ice; and the erosion or quarrying proceeded backwards, leaving precipitous cliffs facing the south, with long gradual slopes towards the north.

Fine examples of this kind of work have been left open to view upon the outcrops of slate on the flanks of Mt. Conness. These slates stand on edge, and for extended level stretches have been planed down to a compact, smooth, yet glacially

scored surface. But on the brink of a cliff the smooth bed gives way to heavy splitting and fracturing, due to the pressure and onward motion of the glacier. The result may be diagrammatically represented in a cross-section, such as is shown in Fig. 3, which is intended to illustrate the breaking over of the edges of cliffs of slate rocks, under the pressure of moving bodies of ice. Similar effects are produced in granitic bed-rock when the cleavage-planes are vertical, and the rock is not strongly supported on the lower or down-hill side. The tendency is to establish vertical cliffs, from which large blocks of rock are detached under the immense pressure of a thick glacier. The erosion thus effected proceeds more rapidly in the bottom of a valley than at the sides; and a cañon or fiord-like gorge results. The operation of the ice may be likened to underhand stoping in mining. While the bed-rock is thus being quarried away, an ample supply of rocks is thereby maintained under the glacier, to form a heavy ground-moraine, independent of a supply by the dropping down of materials from the surface through crevasses.

Thus aided by the structure of the bed-rock, a glacier may cut and crush its way backwards in a gorge with comparative rapidity, and leave a cliff-like termination at the upper end, like those found at the upper end of the Yosemite valley. Similarly, the *cirques* and amphitheaters, with their wall-like sides, may have been formed by former glaciers above the Yosemite.

Deep Mining at the Utica Mine, Angels, California.*

BY J. H. COLLIER, JR., BERKELEY, CAL.

(California Meeting, September, 1899.)

THE mother lode, or mineralized belt, at Angels, in Calaveras county, California, is 3 miles wide. At least, a region of that width has been, and is being, prospected which has shown considerable mineralization. The lode proper divides into three lodes, or groups of veins, at this point. On all of these branches, mines have been operated with more or less success.

* Published also, by permission of the Council, in the souvenir volume, "California Mines and Minerals."

On the most easterly of these three groups, and therefore known locally as the East Lode, is situated the Utica-Stickle mine, in the town of Angels. This lode was in an early day worked as open cut. The cut is still open for some distance, showing the strike of the vein very clearly. The cut would also give the impression that the mine was a simple fissure-deposit. Underground development, however, has shown it to be a much more complicated deposit, at least to mine.

It might more properly be called a gold-bearing mineralized zone rather than a simple vein. The zone consists of a large mass of crushed diabase which, under pressure, has developed a slaty cleavage. The crushed mass has been more or less altered into a schist containing considerable mariposite and white mica. In this mass the ore occurs as large bodies of massive quartz of a brownish-grey color; as masses of quartz veins from 1 to 3 inches wide, interspersed with micaceous schists in a distinctly banded structure; as masses of more or less altered diabase, containing infiltrated silica often in reticulated veinlets; and as impregnations in massive diabase; all containing free gold and auriferous pyrites.

In working upward on the ore-bodies, they sometimes change from massive quartz to a schistose character, and thin out toward the hanging-wall. Cross-cuts run into the foot-wall then show the ore making next the foot-wall, and soon widening out to the original width on its upward course, thus proving that the ledge was cut off by a large horse of diabase, split from the hanging-wall and fallen to the foot-wall. In this way, the ore-body is made up of several parallel lenses or masses, at different points dipping at a high angle to the eastward with a greater southerly pitch, ranging in all from 10 to over 100 feet in width.

With this outline of the general nature of the deposit, the difficulties of mining, more particularly stoping, such a deposit will be better understood. Not only must the stopes be properly supported and economically worked, but the ground must be thoroughly prospected as the work proceeds.

The prospecting must be thorough to ensure the most economical use of the long levels through which the ore is removed. These levels are often driven in extremely hard diabase, and are not only costly in driving and fitting with tracks

and compressed-air pipes, but are often very expensive and difficult to keep open, on account of the settling and crushing of the rock.

The prospecting, on account of the varying character of the ore, offered many difficulties, but the supporting of the stopes offered much more serious difficulties by the extreme width and crushed character of the ore-body. After many difficulties and a serious cave, simple timbering was abandoned in the stopes. At the present time, timbering and stowing are used together. The timber is put in place as fast as there is room, and no opening measuring more than 16 feet vertically is made without stowing. By this means, Mr. Wm. Miller, the foreman, has succeeded in carrying the stoping and prospecting along together, the waste from the prospect cross-cuts in the wall-rock being used for stowing.

Shaft-Sinking.—Before giving a detailed explanation of the excavation of the ore, it will, perhaps, be more logical to speak of the shafts. In all there have been four shafts sunk on this property. The North Utica, 700 feet deep, sunk a short distance back in the foot-wall, is still a good shaft. The South Utica, about 900 feet deep, was sunk on the ledge, and after being kept open to hoist ore through only, at a large expense, had to be abandoned, and now gives some difficulty in stoping around it. The Stickle shaft, 1000 feet deep, was sunk on the ledge and has been almost entirely re-timbered twice, at considerable expense, at one time necessitating the shut-down of the Stickle mine and mill for about a month.

Profiting by the experience with the other shafts, the new Cross shaft, which it is intended to sink to a depth of 1500 feet, on the Stickle mine, has been sunk at a safe distance in the foot-wall from the stopes. As this is the newest shaft, and represents the best practice, I will give a detailed account of it.

After the removal of the surface soil, churn drills were used to put in holes 2 inches in diameter at the collar, tapering to $1\frac{1}{4}$ inches at a depth of 6 or 7 feet. The holes were charged with five or six sticks of No. 2 Judson dynamite, $1\frac{1}{8}$ inches in diameter, and 8 inches long. The powder was exploded by means of safety fuse and percussion caps.

After reaching solid rock, Ingersoll Eclipse machine drills were used. Four drills were run together, two in each end,

hung on bars extending horizontally across the short way of the shaft, about 3 feet from the bottom. When the drilling was completed, one machine was removed from each bar and fastened by means of a rope to the bottom of the bucket and hoisted to the surface. The remaining machines were then turned parallel to their respective bars and clamped. Each bar, with its machine, was then hoisted to the surface also. In setting up the machines, the reverse operation was performed. In this way, the time and labor required to handle the machines were reduced to a minimum. The holes were drilled systematically in eight rows, of three holes each, across the short way of the shaft, with a V-cut in the middle, consisting of six holes. The best results were obtained by drilling the holes from 6 to 7 feet deep. The cut, with the next row on each side, was shot first, and, if it broke well, the others were charged and fired as soon as sufficient rock had been removed to reach them. Each hole was charged with from six to nine sticks of the No. 2 Judson dynamite. At first, safety fuse and percussion caps were used to explode the charges, but later the charges were fired by electricity.

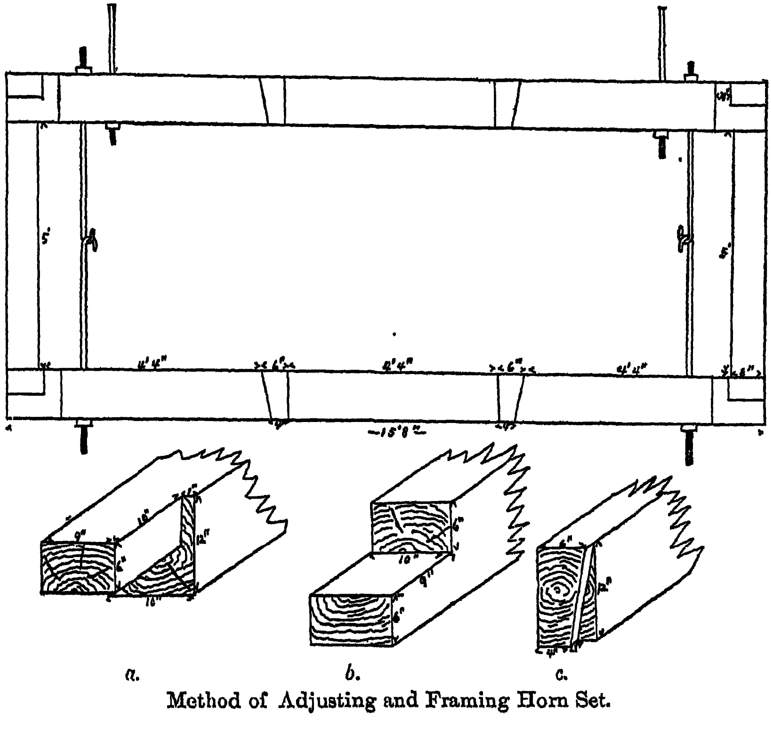
Near the surface, where the ground is loose, the shaft is built up of 12 by 12-inch timber, the ends of the wall-plates and end-pieces being halved together. After reaching solid rock, the shaft is timbered in sets 5 feet apart, which are 5 feet wide and 14 feet long in the clear. By means of the center braces, the shaft is divided into three compartments, each 4 feet 4 inches by 5 feet.

The system of timbering used is what is called the "horn set" (Fig. 1). The wall-plates and end-pieces are framed from 10 by 12-inch Oregon pine. The end-pieces are framed at either end with a 10-inch horn, 9 inches wide and 6 inches thick, leaving a shoulder 1 inch wide, which engages the inner side of either wall-plate (Fig. 1, *a*.). The wall-plates are framed with 9-inch horns at each end, 10 inches wide and 6 inches thick (Fig. 1, *b*.). The center braces are of 6 by 12-inch timber, and are dove-tailed into the wall-plates at either end (Fig. 1, *c*.). The wall-plates have a total length of 15 feet 6 inches, and the end-pieces 6 feet 8 inches. Exactly a foot from each end of the wall-plates is a saw-cut, square across the 12-inch face, for convenience in plumbing when placing the timbers in position. Near each end of the wall-plates are two auger-holes, $1\frac{1}{8}$ inches

in diameter and 6 inches apart, through which are passed hanging-bolts, one passing upward to the set above, the other downward to support the set being put in place. These hangers are made of inch iron, about 4 feet long. On one end is a hook, on the other a thread is cut for about a foot from the end.

The new wall-plate is let down the shaft lengthwise, by means of a chain on the bottom of the skip, which is fastened just above the middle of the timber. The timber thus hangs

FIG. 1.



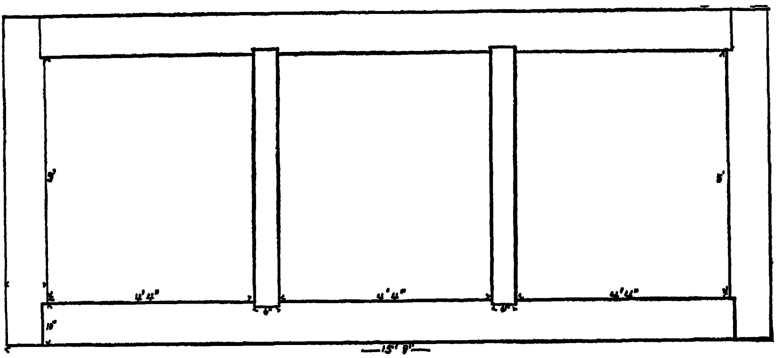
Method of Adjusting and Framing Horn Set.

vertically in the shaft, and, when it has passed the timbers in place, is easily turned into a horizontal position, as the weight is nearly balanced on the chain. A hanger is then inserted in each end with the hook upward, which engages the hook hanging downward from the corresponding end of the plate above. The other wall-plate is similarly placed, and the two are then drawn to their approximate positions by means of the nuts below the plate on the hanger. The end-plates are now dropped into place, and the corner posts, which are 8 inches square and

5 feet long, are successively stood in place, and held by drawing the wall-plate and end piece up against it by means of the hanging-bolts. The center braces are then put in place, and the set lined by means of a plumb-line over the saw-cuts in the set above and the new set. The set is then blocked and wedged securely into place by blocks placed behind the wall-plates opposite center braces and end-pieces, and behind end-pieces opposite wall-plates. By this precaution only compressive strains are brought on the different members of the set. Fig. 2 shows the horn set in place.

The hangers are left in place until two or three sets are put in below, and then removed to be used again. Skip-guides of 6 by 6-inch Oregon pine are fastened to the end-pieces and

FIG. 2.



Horn Set in Place.

center braces by means of lag-screws, with the heads sunk into the guide, so as to prevent the shoe on the skip catching on them. The shaft is lined with 2-inch plank, in 12-foot lengths, behind the wall-plates and end-pieces.

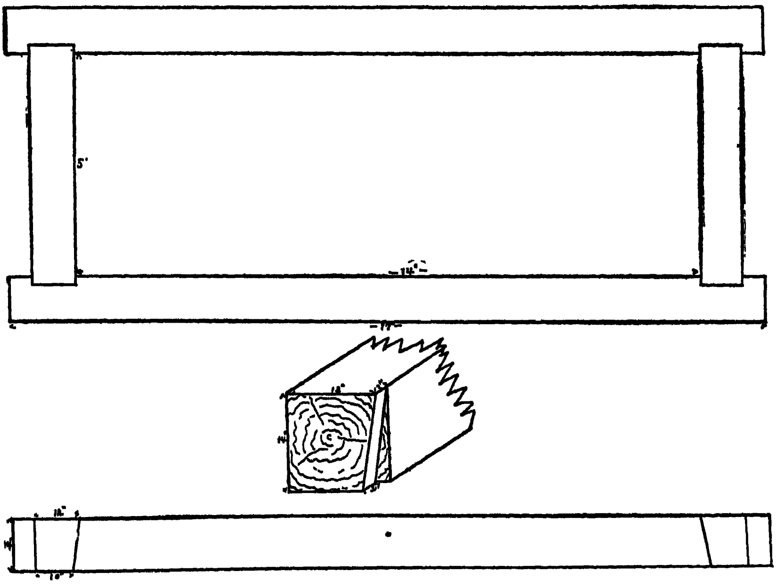
A cheaper form of timbering used in the inclined winze in the Stickle mine is shown in Fig. 3. The framing is simpler and no center braces are used. It answered very well for the purpose, but would not be satisfactory in a working shaft, especially in heavy ground.

In sinking the Cross shaft, the following men were employed: Six machine men and six helpers, divided equally on three 8-hour shifts; two engineers on 12-hour shifts; two machine men with helpers and three timber men, who worked only when the machines were running and were allowed full

time each month. It was found that the timber men could work to the best advantage while the miners were drilling. All hands received three dollars per day. At the end of seven months, the shaft was sunk and timbered to a depth of 825 feet.

The special method used in sinking the Stickle shaft has many strong points. The only serious defect was the problem of ventilation, aggravated by the large amount of "powder-gas" caused by the blasting. This defect detracted very seriously from what otherwise would have been an extremely suc-

FIG. 3.



Box Set in Place, and Method of Framing.

cessful method in regard to both time and economy. The shaft was down some 500 feet when the Utica Company purchased the mine. They immediately started to sink this shaft, and, as the Utica was deeper than this shaft, a level was run over and a raise started. The sinking was carried on practically as already described, except that ground was encountered which gave difficulty in drilling down-holes, while the up-holes in the raise gave no trouble at all.

The raising was cheaper on account of the economical handling of the rock, which was brought about as follows: As soon

as the raise had progressed far enough, a chute door was put in at the bottom. A line of stulls were put in near one side of the raise across the short way, on which were fastened, on the side toward the larger compartment of the raise, a lining of 6-inch lagging. The larger compartment was arranged for a chute, the smaller for a man-way, the ladders being nailed to the lagging.

After drilling a round of holes after the same system as used for a shaft of the same size, the drills and tools were stowed in the man-way. The top of the man-way was covered with heavy timber, leaving a small opening for the miners to pass through. The end of the compressed-air hose was adjusted so as to throw the air into the head of the raise and be safe from the blast. The fuses were fired, and the last man pulled a piece of timber over the remaining opening as he descended. The broken rock then fell into the large compartment, called by the miners the "bull-pen." After 2 or 3 hours, the air would clear enough so that the miners could return to their work. The miners meantime had removed 20 or 30 cars of rock, so that sufficient working space remained at the head of the raise.

This method made it possible to remove the rock at the smallest possible cost, as no shoveling was necessary. After connecting with the shaft above, timbering was commenced, the rock being withdrawn below as the timbering advanced above.

Development Work.—In exploiting the mine, cross-cuts were driven into the ledge every hundred feet. After encountering ledge-matter, drifts were run, taking out the rock from wall to wall. In this manner the full extent of the ore-body was determined, as well as its average value.

These drifts and cross-cuts are never timbered, unless absolutely necessary, until it is determined whether or not they are to be used in the excavation of the ore. Permanent drifts are timbered up substantially with round timber, from 16 to 18 inches in diameter. The ordinary tunnel-sets are used with 7-foot legs, 6 feet apart at the bottom, leaning in at the top to support a 5-foot cap.

The excavating in the levels is done entirely with machines. From 9 to 20 holes are drilled in a round, depending on the nature of the ground. The V-cut is commonly used, generally

with 12 holes, and with the cut vertical. In this system, 3 horizontal rows of 4 holes are drilled. The middle 2 holes of each row are inclined toward each other and come near together, or, in very hard ground, unite. These 2 holes of each row are thus made to explode together. The outer holes of each row are inclined slightly into the wall, in order to prevent the narrowing of the drift.

The upper row always, and sometimes the middle row, is given an upward pitch. The holes will then keep clear in most ground if drilled dry, but when water, under pressure, can be obtained, it is an advantage to keep the holes clear by this means, using a hose and a small nozzle which can be inserted beside the drill in the hole. The bottom row always, and sometimes the middle row, is given a downward pitch sufficient to make the holes hold water well. The water mixes with the drillings and is thrown out as mud by the drill, from time to time, thus keeping the hole clear. The water may be thrown into these holes with a cup or by means of a hose, as before. The water under pressure is best, as it keeps the hole washed almost perfectly free from drillings, thus greatly reducing the time required to drill the holes.

From this last statement must be excepted the case of extremely soft rocks, such as talc and micaceous schists. In these rocks the drill cuts so fast that the dust does not have time to become mixed with the water, and so packs very tight around the shank of the drill. This stops the progress of the drill, and no further headway can be made until the hole is cleaned and water again admitted to the bottom of it. As an example of an extreme case of this difficulty might be mentioned a piece of ground in which a top hole of proper pitch could be drilled dry to a depth of 7 feet in a half-hour, while a hole of same depth with a downward pitch, drilled wet, required fully two hours to drill. In a case of this kind only the bottom holes are drilled wet.

Some ground is found to break better with the cut horizontal. This is done by drilling 4 horizontal rows of 3 holes each, with the holes of the second row from the top pitching downward to meet the corresponding holes of the third row, which pitch upward.

In ground which is difficult to break, it is found necessary to

increase the number of cut-holes from 6 to 8. In still more difficult ground the back-holes also have to be increased, so that as many as 24 holes are found necessary. It is also found necessary, sometimes, to increase the width of the drift, in order to give the cut-holes a greater cut. Whatever system is used, the holes are given as nearly as possible the same load. The most central are arranged to be shot first, followed by the other cut-holes in pairs. The middle holes of the adjoining rows, on either side of the cut, come next, followed by the remaining holes in each row.

If the ground is extremely schistose, or if there is a slip or gouge-seam following along one wall, 9 holes may be sufficient for the first breaking to the slip or the side of the drift. If there is no gouge-seam or slip, the drift may be kept straight by breaking alternately to one side and the other.

The easiest and the most difficult ground to break have only a slight difference in structure. They are both schistose, and have an extremely gnarled structure. But the difficult ground has been filled with infiltrated silica, which has so hardened it that it has to be literally burned out with powder.

Occasionally soft and running ground is encountered, which gives some trouble. The difficulties offered by this sort of ground are overcome by an ingenious system of poling, which will be described in connection with the stoping.

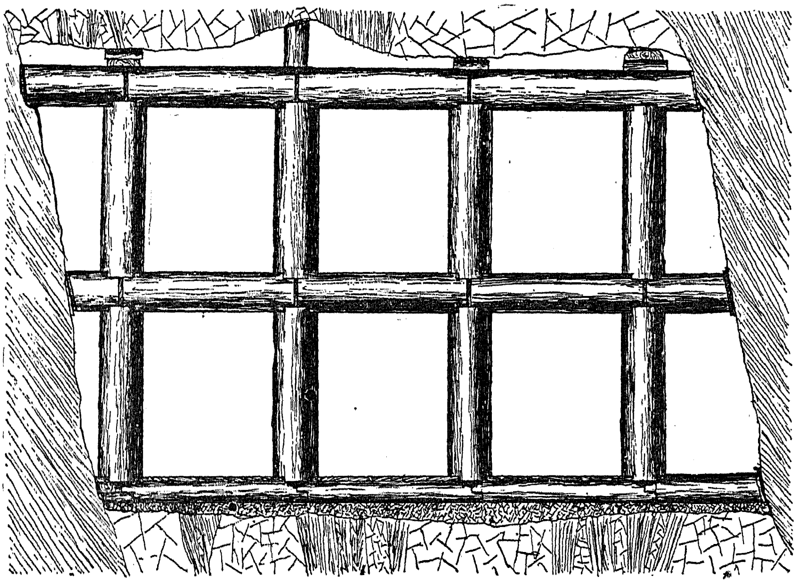
Stoping.—In the excavating operations, an enormous amount of timber is used. This timber is all round and comes in 16-foot lengths, from 12 to 26 inches in diameter. Poles are from 6 to 12 inches in diameter, and come in 20-foot lengths, which are cut in two for use in the mine. The posts for the sets in the stopes are generally made from the timber of the largest diameter. The logs are cut in two, in the middle, for stope timbers. Posts are framed to 14 inches on two opposite corresponding sides of each end, to a distance of 3 inches from each end. The caps are framed on one side at each end, leaving 7 feet between the joggles and about 6-inch horns.

A stope is started by breasting out the ore to the full width of the deposit. Cross-cuts are run into both walls, to be sure that all the ore has been removed. The opening is then timbered with 8-foot stope sets. If the ground is solid, no timbering is done until the whole mass of the rock covering the area

of the stope has been removed. The posts are then set in the solid rock, with 6-inch spreaders and 12-inch round brace-sprags between the posts at the bottom. A floor is then laid over the spreaders.

If the rock is loose or soft, one set is put in at a time as fast as room is made for them. In the soft ground heavy sills are laid, as shown in Fig. 4, to give a solid foundation for the posts. Sills are not, as is generally supposed, an advantage in working up under an old stope. Good floors laid across the spreaders, even though they have been in place so long as to be

FIG. 4.



Timbering with Heavy Sills in Soft Ground.

badly decayed, are found to be more serviceable than sills. The sills are seldom in place when reached, and have to be caught up securely, or they are liable, by their own movement, to start a serious run in the waste above them. After the sill floor is opened and timbered (as shown in Fig. 4, which shows a stope 35 feet wide), a raise following the foot-wall is run up to the level above.

This raise is necessary for the proper ventilation of the stope, as well as the economical introduction of timber and waste into the stope; the timber and waste being thrown down the raise

into the stope. The raise is located in the most convenient part of the stope, and, if possible, where there is a seam of gouge on the foot-wall, which greatly lessens the cost of the work by lessening the difficulty of breaking the ground. If the rock is hard and solid, machines are used and the raise is timbered with full-sized stope sets, if timbering is necessary; so that, as the stope is carried up, the timber of the stope is joined on to that of the raise. If the ground is loose, the work is all done by hand, and the raise is built up solid with round timber, halved together at the ends, making the raise 4 feet square in the clear.

The second floor above the level is now started from the raise, the ore falling to the sill floors, where it is shoveled into cars. After this floor is excavated, a set for the full length of the stope is lagged on tops and sides with half-round slabs, made by cutting 12-inch logs, 8 feet long, in two lengthwise. This set is then kept open for the gangway, along the line of which the chutes and man-ways, leading up into the stope, are started. All the remaining space to the top of the sill floor set is now filled with waste. This waste is obtained from three sources within the mine: first, from the vein-rock, by hand-sorting in the mine; second, from cross-cuts run in the wall-rock from the different floors of the stope, for the double purpose of prospecting the ground and supplying the waste; and, third, from the dead-work in different parts of the mine, which is brought in through the raise from the level above.

From this time the chutes and man-ways are carried up by means of cribbing (shown in Fig. 5), to within one set of the back of the stope. When the ground is heavy, similar cribbing is used to help support the ground. In wide and heavy stopes, a row of such cribbing is generally put in, extending the full length of the middle of the stope, and is stowed with waste as rapidly as possible.

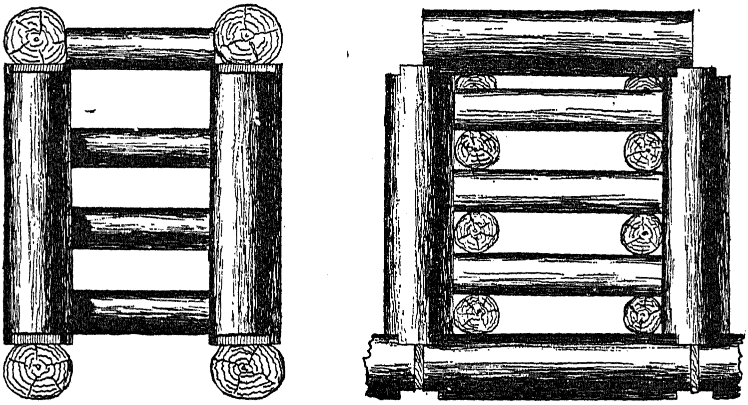
The different floors are started successively from the raise. As soon as a floor has been advanced far enough from the raise to prevent the mixing of the quartz and waste, filling is commenced by throwing waste down the raise. When the floor is completed, the lower floor, remote from the raise, is stowed with waste from the cross-cuts. In order to supply sufficient material for this purpose, the cross-cuts, which start out with

small dimensions, are widened out into large chambers. In this way no opening in the stope is kept open to a greater vertical height than 16 feet.

When a level is being worked, a large mass of rock is left in place in the ledge, opposite the shaft, until the last thing before the level is abandoned. This precaution protects the shaft, which is already weakened by the cutting of the station.

When the vein-matter is badly crushed and broken up, an ingenious system of lagging, called poling, is used. Poles are run out over a cap or sprag—depending on the direction of the work, whether with or across the vein—which supports the ground until the timber is in place (Fig. 6). In some cases the

FIG. 5.



Cribbing for Chutes and Man-ways.

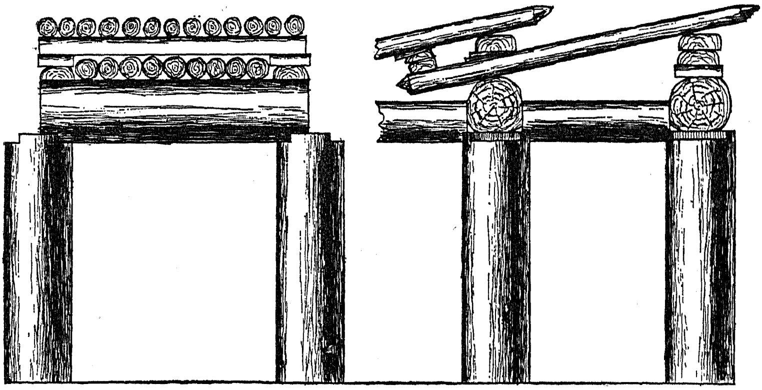
poles are a necessity to prevent the ground from running, in others they are put in more for a protection to the miners working beneath them. In the latter case the trouble is caused by detached pieces which continually slack away, due to the presence of water and slight settling.

In running ground, the poling has to be performed with great care. The ends of the poles are sharpened and worked in over the cap all together by working the rock loose around the points with a bar and driving the poles ahead with a hammer. As the poles are advanced over the cap, the broken rock is raked back from the points of the poles and left standing on the natural slope to prevent its running. Also side-poles are put in, if necessary, beginning next the roof and

working them in as the rock is removed, and the face breast-boarded to prevent the loose rock running around the points of the poles. Proceeding in this way, room is made for one set at a time.

The details of this work are shown in two sets of drawings (Figs. 6 and 7). When the set of timbers is put in beneath the poles, a bridge-piece is put in supporting them, so that they cannot come down on the cap before the next poles are started. After the poles for the next set are run out over the cap, wedges are inserted between the poles and the bridge-piece, and driven until the weight is taken off the short blocks supporting the bridge-piece. The blocks are then replaced by poles. Where the ground will permit, pieces of 2-inch plank

FIG. 6.



Poling.

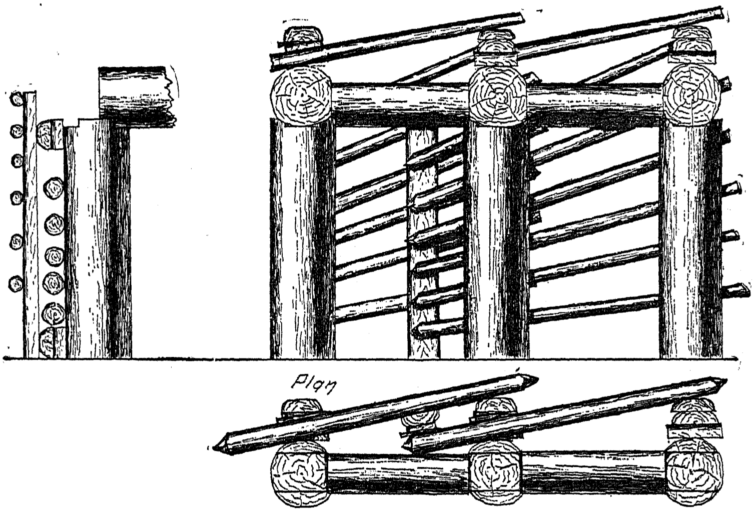
are inserted cross-wise behind the poles, this adding greatly to the efficiency of the poles.

The system seems to have all the merits of the square-set system used on the Comstock, at the same time being cheaper and more flexible. It is cheaper because the cheaper round timber is used and the framing is much more simple. Much of the framing is done in the mine while waiting for the partially framed timber to come from the surface, which always causes more or less delay when several crews are to be supplied through the same shaft.

It will be remembered that the caps were only framed on one side before being sent into the mine. There are several reasons for this. As the logs are not always exactly 16 feet

long nor cut square on the end, it is found necessary to leave a space between the ends of the caps of about 2 inches to allow for this irregularity. This is brought about by framing the ends of the posts to 14 inches, and the caps so that they measure 7 feet between joggles, which, if the log was exactly 16 feet, would leave 6-inch horns. If the side-pressure was great enough, this space might be reduced the full 2 inches, thus reducing the hitch formed by the two adjacent caps (if they had been framed) to 12, instead of 14 inches. Again, the ends of the posts not being exactly square, they would raise one of the caps higher than the other. Again, the caps, being made from

FIG. 7.



Details of Poling.

the logs, have the natural taper of the tree, and so the ends are not of equal dimensions, the difference in diameter being often as much as 6 inches. As the posts in the stope do not settle equally, use is made of this irregularity to keep the line of the caps horizontal. The end of the cap of the largest diameter is placed on the lowest post. When the next set above is put in, the joggle over the higher post is cut deeper than the one over the lower post of the under set. It is, therefore, evident that the size, to which the end of the cap is framed, depends on the circumstances in the stope, and, thus, can only be done to advantage in the stope.

The general dip of the ore-body is nearly vertical, but in places where it bulges the wall-rock sometimes has a pitch of 45°. The timbering is adapted to this case by first leaving a horn on the cap extending over the post nearest the foot-wall. When this horn must be so long as to greatly increase the weight of the cap, a short butt-cap is used instead. This butt-cap is framed the same as an ordinary cap on one end, on the other it is beveled to fit the wall-rock. The length of the butt-cap is increased as the wall recedes, until the distance between the post and the wall-rock becomes great enough for a full set. A hitch is then cut in the foot-wall for another post. While the caps on the foot-wall side have been lengthened, those on the hanging-wall side have been correspondingly shortened. Full sets are also dropped on the hanging-wall side as they are taken up on the foot-wall side. By these means, the system may be applied to a ledge which has a comparatively small angle of dip as well as considerable width.

The method, as a whole, has as much rigidity as the extreme width and the constant settling of the ledge will permit, combined with a sufficiently low cost, to allow of its being applied in the excavation of large bodies of comparatively low-grade ores.

Hoisting and Tramming.—Each shaft is supplied with a double acting water-power hoist. Two Dodd water-wheels, 9 feet in diameter, are placed on the pinion shaft in reversed position, so that power may be applied to run the hoist in either direction. The water is applied through three nozzles, so that the power can be readily proportioned to the load. The nozzles are served by a 10-inch wrought-iron pipe, which delivers the water under a head of 420 feet, giving a standing pressure of 180 pounds, which falls to 130 when the hoist is in operation.

Wire ropes, 1 inch in diameter, are used on 5-foot drums. The ropes, which last from three to eight months, are inspected daily, and at the least sign of failure are condemned and removed. The rope passes from the drum over a 7-foot sheave-wheel at the top of a gallows frame, 80 feet high.

Two skips are used, each covered by a sheet-iron bonnet and supplied with an automatic safety clutch. When the skip descends faster than a certain rate of speed, which can be regulated, a parachute under the bonnet raises and releases the

clutches which grip the guides, and so arrests the descent of the skip.

The rock skip is constructed of sheet-iron, with a capacity of 2 tons. It is loaded from the chutes in the shaft at the different levels. At the surface it is dumped automatically by means of a curved switch, which turns the sheet-iron box, containing the ore, out of the line of the guides over a chute leading to the rock-breaker. The frame remains on the guides, and, as it ascends, it turns the box bottom up on the axis at the bottom of the frame. The skip frame is then lowered, which turns the box back again into position, where it is locked automatically.

The water skip is also made of sheet-iron, 3 feet square and 8 feet long, holding about 500 gallons of water. The tank is filled through a butterfly valve in the bottom of the tank. When it reaches the surface, one wing of the valve is opened automatically by a system of levers, which are actuated by a bumper on the gallows frame, and the water is discharged into a tank at the side of the shaft.

On the levels, ton cars are used to transport the ore from the stopes to the shaft. The cars are constructed of sheet-iron and run on light T-iron rails laid on 3-inch ties. The tracks are laid along the line of the chutes leading up into the stopes. The cars are loaded from these chutes and run out to the shaft where they are dumped into a chute, which has a capacity of 50 or 60 tons. This chute has a door opening into the shaft through which the skip is loaded.

Pumps.—The drainage of the mine is further provided for by a pumping-plant consisting of two 7-inch bucket- and one 8-inch plunger-pumps. This plant is run by a 6-foot Dodd wheel, geared to a long, reciprocating rod in the shaft, which supplies the power to the pumps at the several stations in the shaft. The capacity of this plant is about 75 gallons per minute, from a depth of 900 feet. Most of the water is handled, however, by the water skip.

To supply a 60-stamp mill with about 300 tons per day requires two shifts of forty-five men each, consisting of miners, helpers and shovelers, working on ten-hour shifts. The two shifts alternate on night- and day-shift, changing every two weeks. Each shift consists, approximately, of twelve miners,

each with a helper, about fifteen shovelers, and six men running the cars on the level. This division of the working-force is not constant, as it depends on the conditions in the mine, which are constantly changing. When the broken rock is plenty and easy to get at, some of the miners may be put to shoveling pay-rock, and some of the shovelers put to work on the stowing. On the other hand, if rock is short, some of the shovelers may be added to the force of miners. The miners are paid $3 per day; the helpers, shovelers and carmen are paid $2.50 per day. In addition to these two shifts, a crew of ten timbermen is also necessary, receiving $3 per day.

I would have been glad to add data as to the cost of the excavation of the ore, but as I was not in possession of any official data, I thought it would not be best to give an estimate without permission of the Companies. For the opportunity to collect the information which this paper contains, I am indebted to the kindness of Mr. Wm. Miller, under whom I have worked for about two years, as well as during the vacation periods of my Junior and Senior years at the University of California. I am also indebted to Mr. C. D. Lane and Mr. Alvinza Hayward, through whose courtesy not only I, but several others in the College of Mines, have been able to gain considerable valuable experience in the mines at Angels.

The Tangential Water-Wheel.

BY W. A. DOBLE, SAN FRANCISCO, CAL.

(California Meeting, September, 1899.)

OPINIONS differ as to whether the water-wheel almost universally known as the Pelton type belongs to the impulse, the tangential, the reactive, the jet or the percussion class, or to a cross between two or more of these classes. The fact is, that for an almost infinitesimal part of a second the axis of the jet of water strikes the bucket of this wheel at a true tangent to its base-line. The percussion of the water, striking the bucket, imparts an impulse to the wheel, causing rotation; and generally the bucket is so shaped that the direction of the jet is

reversed almost back upon itself. This reversed flow, as it emerges from the bucket, is reactive, and tends to further increase of the speed and power of the rotation. There is hardly a law in all the vast category of the application of forces which is not applicable to the resolution of the problems embodied in the design and operation of these water-wheels. To avoid objection, we may term the general type "tangential," as distinctive from water-wheels of the turbine class.

The true principle of the tangential wheel was illustrated and described by Branca in 1629. This device was used in Loretto, Italy, and is pictured as a horizontal wheel with vanes or buckets, upon which a jet of steam impinged, causing rotation. This was imparted through a bevel-gear to a shaft that dropped pestles into respective mortars for grinding, as in a stamp-mill. In later times Poncelet (1827) demonstrated the inefficiency of flat vanes, and substituted therefor forms which were concave and tangent to the jet, so that the water, on entering, would run up inclines and back again, thus imparting energy to the water-wheel during its entire course. This was the first form of tangential wheel to "provide graduated entrances and avoid shocks, concussions or eddies in the water." Prior to 1822, however, James White had used semi-circular buckets; and in 1843 Madame de Girard of Paris brought out the semi-circular buckets which have since become widely known as the distinctive feature of the Girard water-wheel. De Canson (1847) used quarter-circle buckets to which the jet was applied normally, the water escaping tangentially. Borda, in his memoirs (1767), gave the sum and substance of tangential water-wheel principles when he wrote: "To produce its total mechanical effects, the water serving as a motive power must be brought on to the wheel with impulse, and quit it without velocity." Euler's description of the first-constructed turbine (1754) considered the motion of water in a semi-circle, while imparting power to a wheel. Dingler (1858) gave forms of water-ways which conform well with the half-circle motion of water in driving a tangential wheel. Navier (1819) refers to the mills of Provence and portions of Dauphiny, which had spoon-shaped buckets, receiving the stroke of water, delivered generally through inclined troughs. Again, in 1819, Navier wrote: "The necessity of disposing machines in such wise that there should be no

shock, although established long ago, both by theory and practice, is not so generally recognized as could be desired. . . . . Mr. Brewster also announces that he has frequently had the idea that a hydraulic machine of great efficiency could be constructed by combining the impulsion with the reaction of water." Ferguson (1826) described an undershot wheel, having buckets inclined to the radius and "driven partly by impulse." Schwamkrug, prior to 1850, constructed vertical tangential wheels with outward flow. In short, numerous other instances might be cited to prove that the modern tangential water-wheel has been brought to its present state of high efficiency through gradual evolution from times of antiquity.

In bold relief, however, stand the names of a few men who, in recent years, have developed these wheels from the crude devices of the first part of the century to the high plane which they now occupy as prime movers in the industry of the world. To make reference to the work of these inventors, and then to discuss the engineering features involved in the design and construction of highly efficient tangential water-wheels, and to consider the tendency of modern practice in this respect, is the purpose of this paper.

Tangential water-wheels are essentially a Californian development, in that their perfection was brought about through the natural conditions imposed in the mining regions of the Golden State, where limited quantities of water at high heads constituted practically the only form of water-power available for the working of mines and mills. But the use of water in limited quantities at high heads necessitated the use of a form of water-wheel entirely distinct from the familiar undershot and overshot types. Others, however, had been working on the same problem as that which confronted the California pioneers, and among these was notably Jearum Atkins, to whom must undoubtedly be given the credit for having been the first to grasp the true principles underlying the operation of the tangential water-wheel by impulse and reaction, and to design a wheel of this type which soundly embodied modern ideas in that direction.

The remarkably advanced mechanical ideas of Atkins were first brought before the engineering world by Mr. R. D. O. Smith* and simultaneously by Mr. John Richards† in articles

* *Cassier's Magazine*, vol. v., p. 109. † *Id.*, p. 117.

published in December, 1893. Among his other inventions, Atkins applied in 1853 for a United States patent on a new form of water-wheel. The patent was not issued until August 10, 1875; and its drawings and specifications show that the inventor had two prime ideas in mind, the minor of which was the building of a wheel containing semi-circular water-ways, of even width and area throughout, and parallel with the axis of the wheel; the water being applied to these buckets simultaneously from a trunk surrounding the wheel. One of the drawings in the Atkins patent is shown in Fig. 1. The major idea of the Atkins patent is that the water in the wheel, as well as the wheel itself, should move at half the speed of the entering water, to facilitate which result, Atkins proposed that the area of the water-way *through* the wheel should be double the area of the water-way *to* the wheel. Moreover, his specification declared that, since the peripheral speed of the wheel would be half the velocity of the jet, and since the direction of the jet would be reversed by the shape of the bucket, the water must leave the wheel without velocity, or, in other words, the water should give up all its energy to the wheel.

So far as is known, Atkins never built a wheel upon these principles; but those who know of the serious misfortunes which always pursued him can easily understand why this was never done. The commercial value of the Atkins wheel has, therefore, never been determined. But, while it differed in shape from the present forms of tangential wheels, and had no dividing-wedge in its buckets, it clearly embodied the fundamental principles of the modern tangential wheel, namely, that the water be applied to the periphery of the wheel; that the peripheral velocity of the wheel be approximately one-half of the velocity of the jet; that the direction of flow of the stream be reversed, so that the wheel may absorb the reactive energy of the jet; and that the water leave the wheel without velocity. A significant evidence of the lack of appreciation which American engineers have shown for the value of the Atkins patent is found in the fact that, seven years after it was granted, Messrs. Escher, Wyss & Co., of Zurich, Switzerland, began making water-wheels of the Atkins type, and the practice soon extended all over Europe, especially France. The Atkins type of wheel came back to this country in 1890, however, through the

plans for the water-wheels at Niagara, which were made from drawings furnished by Messrs. Faesch & Picard of Geneva, Switzerland, who, with four other European firms, tendered full plans for the construction of these wheels.

Opinions differ as to the relevancy of the Atkins wheel to a discussion of the priority of invention of the tangential wheel; but in view of the plain facts, I must confess my inability to understand any contention that Atkins' invention has no bearing on that subject. It is true that he neither proposed the use of a split bucket nor suggested that the buckets should enter and leave the stream without shock; nor, indeed, did his wheel have the form or many other features possessed by the tangential wheels of to-day; nevertheless it embodied their basic principles with thoroughness and clearness. The truth of this was recognized in the two articles already referred to. Mr. Smith says:

> "The writer does not propose to discuss the mechanical or theoretical value of this invention further than to suggest that, while, for the enormous pressures under which the Pelton wheel acts, the round nozzle and free jet may be a preferable form, it does not appear to follow that the Pelton wheel is necessarily a more perfect form than the Atkins wheel with its semi-circular buckets, its confined water, and rectangular jets under low pressure. The advantages of the Pelton wheel may be quite dependent upon other considerations, viz., the absence of inclosures and joints capable of withstanding enormous hydraulic pressures, and the absence of friction incident to close fittings capable of withstanding such pressures. It would seem to the writer that the Atkins wheel approaches theoretical perfection as closely as human mechanisms ever approach it, and that the Pelton wheel is a wonderfully successful adaptation of Atkins' discovery to special circumstances."

Mr. Richards says:

> "In this country the earliest understanding of impulsive action, as distinguished from pressure in turbine water-wheels, seems to have been arrived at by Mr. Jearum Atkins."

And after describing the Atkins wheel and the principles involved therein, Mr. Richards concludes:

> "Mr. Atkins, more than forty years ago, had thus arrived at a point in this branch of engineering investigation that not very many of the present day have reached; and much honor is due him for his researches, which, if followed out at the time, might have added millions of wealth to this country."

But the Atkins wheel was unknown until the patent was issued in 1875; and in the interim between his application

for a patent and its issue, the miners of California had independently developed the "hurdy-gurdy" wheel, which, though crude, was the immediate forerunner of the modern type of tangential wheel. The original hurdy-gurdy wheel (named after the musical instrument in which a revolving cylinder takes the place of a fiddle-bow, operating upon strings) resembled a circular-saw with straight-cut teeth more than anything else; the chief difference being that the hurdy-gurdy was made of wood, varying in thickness up to 2 or 3 inches or more. The jet was applied exactly as in present forms of tangential wheels; and the power derived therefrom showed an efficiency of 40 per cent. or thereabouts.

The hurdy-gurdy wheel was made of blocks of wood about 4 inches thick, cut out, as stated, like the teeth of a circular-saw, about 8 inches apart. These teeth or buckets were then closed in by casings of wood which formed the sides of the wheel; and from these sides four arms or spokes were morticed into a log, the end of which was fitted with a round gudgeon for a bearing. The gudgeon was then placed in a live oak block, which had previously been gouged out for the bearing, very roughly, by the way, because of the poor quality of the tools available to the miner of those days. The water was applied at first in the form of a jet, emanating from a hole bored into the end of a wooden block with which the pipe had been plugged. The pipe-line was sometimes of sheet-iron and sometimes of wood. With heads varying from 40 to 50 feet, square wooden pipes were frequently used. These were merely square wooden boxes, bolted together with iron rods, if such could be secured; otherwise the box would be clamped together by means of wooden frames, cleats and wedges.

Such hurdy-gurdy wheels and wooden pipe-lines were considered good practice in 1854; but, as time passed and small quartz-mills were erected, it was found that the sphere of usefulness of the hurdy-gurdy could be enlarged to include the driving of stamp-mills, which it did fairly well, when brass nozzles and moderately high heads were used, as became the common practice. The question of efficiency was not taken into consideration until hurdy-gurdy wheels were applied to the operation of large stamp-mills, when it was found that the hurdy-gurdy would not develop the power required to give the

mill the proper speed. This was attributed to the fact that, as the buckets were closed in at each side and on the bottom, the waste-water could not discharge itself freely, and, in consequence, the buckets would remain full during the greater portion of the time they remained in the jet, while all additional water directed against the bucket after it was filled merely slipped over the face of the water already in the bucket. The hurdy-gurdy was a pure impact wheel; and, at that time, little if any thought had been given to the reaction of water as applied to the present forms of tangential wheels.*

The gradual evolution of the hurdy-gurdy wheel into the modern tangential wheel was centered in operations mainly confined to Amador and Calaveras counties in California. About 1866 the Pacific Iron-works of San Francisco made a cast-iron wheel to drive a 16-stamp mill at the Gwin mine in Calaveras county, which was the first wheel to embody a material change in the action of the water from that which occurred in the hurdy-gurdy. It had a center-discharge, for the purpose of diverting the direction of the stream, so that the energy which the stream still possessed, after it had lost the portion due to the initial impact could be rendered useful by being guided in a reactive course. The great success of this wheel, as compared with the hurdy-gurdy, proved to be the turning-point in the building of this class of wheels; and it was realized at once that the old hurdy-gurdy had seen its best days.

The next marked improvement was undoubtedly due to Mr. S. N. Knight of Sutter Creek, Cal., who brought out the cup-shaped bucket since universally known as characterizing the Knight wheel. This wheel is of the true tangential type, and its buckets are so shaped that they have both side- and inward discharges, while most of the later types of bucket have mainly side-discharges. The stream of water applied to the Knight bucket is of rectilinear cross-section. The first Knight wheel, made in 1870, presented no radical departure from the present form of the Knight wheel. In 1872 a Knight wheel, placed in the Gwin mine to operate a 20-stamp mill, was first equipped with buckets having an inward discharge; these were then

* The author gratefully acknowledges his indebtedness to Mr. S. N. Knight, of Sutter Creek, Cal., for most of the information given concerning hurdy-gurdy wheels.

changed so as to have side-discharges; and finally the present form was adopted, which has both inward and side-discharges. This being an important stage in the development of the tangential wheel, it is pertinent to quote the following statement by Mr. Knight concerning the early history of the invention:

"About 1870 I, in common with others, made water-wheels entirely out of wood. The buckets were shaped like saw-teeth, and wooden flanges covered the sides of the buckets, to confine the water; a round nozzle was used; and the general results were considered at that time highly satisfactory. The next step, about two years later, was to make a wooden wheel with iron buckets, giving them a curve and discharging the water toward the center of the wheel—still using, however, the round nozzle.

"Two years later than this, Nicholas J. Colman patented a wheel which had a bucket shaped very much like the present Pelton bucket; the stream splitting and curving off to each side. He, for lack of means, I understand, did nothing with it.

"After two or three years more had passed, I made an improvement by using a curved iron bucket and having the discharge towards the center and to one side, much the same as the Collins (Pacific Iron-works) wheel, still using the round nozzle.

"After continued experiments with the nozzle, Collins found it did not fill the general requirements; he could not cover enough bucket-space along the periphery of the wheel, without covering an equal space in the width of the bucket, by increasing the diameter of the round nozzle.

"This induced him to try an elliptical or oblong nozzle; and the first wheel of this character was placed in the Lamphear mine, at Mokelumne Hill, and it was quickly followed by two others, so satisfactorily did they work.

"From these wheels sprang the present Knight water-wheel; for here it was that I conceived the idea of abandoning entirely any direct modification of the round nozzle, and made the opening a narrow rectangular slit.

"The round nozzle did well enough where small quantities of water were used; but upon using considerable water, the nozzle became so large that, while the upper edge could be brought near the wheel the lower edge was far away, and it reduced the power materially; so the slit was determined upon. More than one nozzle was also tried, but it did not prove satisfactory.

"In 1875 the first wheel of the present style was placed in the Lincoln mine, at Sutter Creek, and from that time various improvements have been made in the size and arrangement of the slits in the nozzle and shape of the buckets."

We now come to a vexed question, namely, the origin of the jet-splitting wedge. If the records of the United States Patent Office form any criterion, or if after-events of commercial import have any significance, the credit for the wedge-shaped bucket is due to Mr. Nicholas J. Colman of Railroad Flat, Cal. (1873)*. The specifications of the Colman patent de-

* U. S. Letters Patent, No. 135,891, Feb. 18, 1873.

scribe a tangential wheel built somewhat after the hurdy-gurdy principle, but with sharply defined buckets containing wedges for dividing the stream. In substance, the specifications describe the action of the water to be as follows: Leaving the penstock, the water strikes the wedge and back of the bucket, exerting its first force upon this back. The wedge divides the water, which then follows the upwardly and outwardly sweeping curve of the discharge-passage, still exerting its force upon the full length of the buckets, while combining its momentum with the centrifugal force acquired by the wheel, and finally discharging at the periphery, through openings which are provided therefor. The two claims of the Colman patent read as follows:

1. The wedge- or plow-shaped buckets, dividing the water at *e*, and curving toward the sides at *f*, substantially as and for the purpose described.

2. In combination with the wedge-shaped buckets, as shown, the upwardly curving buckets *g*, discharging at the periphery, substantially as and for the purpose herein described.

Mr. Knight is my authority for the statement that, to the best of his knowledge, Mr. Colman made a bucket for splitting the stream as early as 1870; but so far as Mr. Knight knows, none of the Colman wheels were ever put into use. In any event, it is certain that tangential wheels made under the Colman patent were never brought before the public as a regular manufacture, nor did that patent exert any influence in molding the form of the bucket of the tangential wheel of the present time. It is interesting to note, however, that a few years before the expiration of the Colman patent it was bought from the inventor for $500—which proved to be a very good investment, as the purchaser secured thereby a royalty of $1 for each foot of the diameter of every Pelton water-wheel sold during the life of the Colman patent, upon which basis of settlement he netted about $15,000.

There are several others who claim the invention of the Pelton form of bucket—that is, the bucket containing a dividing-wedge. Among these claimants may be named as prominent Mr. Joseph Moore of the Risdon Iron and Locomotive-works, San Francisco; Prof. F. G. Hesse, Professor of Mechanical Engineering of the University of California; and Mr.

L. A. Pelton, inventor of the Pelton water-wheel. According to the statements of these three parties, given below, the divided-wedge form of bucket was invented between 1865 and, say, 1878.

In February, 1897, Mr. Moore issued a monograph in which he claims to be the inventor of the then so-called "California tangential water-wheel with reaction-buckets." From 1860 to 1880 Mr. Moore was manager, constructing engineer, director and part owner of the Risdon Iron-works, the records of which institution bear irrefutable support to the statements of his monograph. The substance of this pamphlet, which is quite long, is that in March, 1874, Mr. G. Tiscornia of San Andreas, Calaveras county, Cal., applied to the Risdon Iron-works for information respecting a water-wheel to drive a quartz-mill. After computing the amount of water and head available, Mr. Moore found that it was impracticable to perform the specified work with the hurdy-gurdy wheels then used, in view of which he "suggested to Mr. Tiscornia a change of buckets, so as to gain reactive effects, also avoid oblique impingements," further stating that he (Moore) would send Tiscornia a sketch of buckets accordingly. "After some correspondence on the subject," continues Mr. Moore, "I made, on March 29, 1874, on an order-blank of the Risdon Iron-works, the sketch" which is reproduced herewith as Fig. 2. On the opposite side of the sheet containing the sketch Mr. Moore wrote a letter to Mr. Tiscornia, dated March 29, 1874, which stated:

"You can see the principle (of the wheel), viz.: to receive the water without shock, at an angle of about 10 degrees, and deliver it at the same, or say 15 degrees. This reaction-water will have no velocity when at proper speed, but will probably react or spout in the opposite direction; really, its best speed is when it drops straight down, but practically it is best to leave enough velocity in it to clear the wheel."

On the next day (March 30, 1874) Mr. Moore again wrote to Mr. Tiscornia, the letter being as follows:

"Yours of the 26th just came to hand. Last night I mailed you a sketch of a bucket which I think is quite superior to the one you sketched. It has the same advantages that you expect with yours; that is, reverses the direction of the water without shock, which is all that can be accomplished by any bucket; but mine has the further advantage of getting rid of the water without its coming in contact with the next bucket, which is a decided advantage, as you see that the water has become stationary with respect to the wheel, or, what is more likely,

has got a backward motion; then the following bucket must impart the velocity of the wheel to the water again, which is just the same as an overshot wheel running in back-water. The proper way is to do the work and get rid of the water, and this, as you see, is accomplished by my bucket, upon which there is no patent."

The monograph then expresses the opinion that "not only was the theory (of the tangential wheel) thus laid down, but it was carried out in a manner not since improved upon."

The order was duly entered in the Risdon order-book, April 7, 1874, for "a set of hurdy-gurdy wheel buckets, as per pattern and sketch." The buckets were finished and shipped by express to Mr. Tiscornia on April 13, 1874, and on the same date Mr. Moore wrote to Mr. Tiscornia, saying, among other things:

"You will find, if you let the water play upon the center, that it shoots back with sufficient clearance to free the following bucket. . . . These buckets ought to be 7 to 9 inches apart and the water led on the wheel at an angle not more than 15 degrees, and from a good nozzle, as close up as possible to the buckets."

None of the old castings for the Moore buckets can be found; but, fortunately, the pattern from which they were cast was found in the pattern-room of the Risdon Iron-works. The pamphlet contains front and rear views of this pattern (Fig. 3), together with a transverse section thereof (Fig. 4) made from templates fitted to it, the scale being reduced by photography to one-half of the original size. A diagram showing the method of mounting the buckets is also reproduced (Fig. 5). At the Risdon Iron-works may be seen the originals of these patterns, drawings and documents, together with the affidavit of George Cummin, general foreman of the works, as to when the buckets were made, and the affidavit of John F. Skivington, who made the pattern for the bucket, and who is still foreman of the Risdon pattern-shop.

Mr. Moore's pamphlet (p. 7) states that, "after some correspondence on the subject," he made the sketch referred to. The probability is that this correspondence followed an interview with Professor Hesse, which was had presumably with the idea of confirming, as far as possible, Mr. Moore's theories.

In May, 1897, Mr. Pelton published a pamphlet on the "Origin of the Pelton Water-wheel," containing the follow-

ing statement, which may therefore be accepted as an authentic presentation of Mr. Pelton's claims to the priority of invention:

"I crossed the plains from Ohio in 1850, and engaged in mining almost continuously until 1864, when I took up mill-wrighting, in connection with mining, at Camptonville, Yuba county, and other places north of that town, in which business I was employed until 1878; and during this period I constructed a number of water-wheels, of the type commonly known as hurdy-gurdy wheels, having an efficiency of 40 per cent. and upwards, according to the style of buckets used. Here, I conceived, was a chance for improvement; and early in 1878 I procured the necessary appliances for testing the efficiency of buckets for pressure- or jet-wheels, and devoted most of the time for two years following to designing a bucket which would give a higher efficiency. I tested between thirty and forty different shapes of buckets, and finally noticed that a curved bucket having a jet-strike on the side, as in Fig. 7, instead of in its center (Fig. 6), gave a marked increase in the efficiency of the wheel, but caused an end-thrust against one bearing. To avoid this, I experimented with placing the buckets alternately, as in Fig. 8, when it was but a step to combining the two curved buckets and splitting the stream, as in Fig. 9. This bucket, when tested, gave such astonishing results that I immediately took steps to secure my invention.

"I introduced my wheel to the public, after obtaining a patent, in October, 1880, and claim to have invented what is known as the 'Pelton water-wheel' independently, and without any knowledge whatever or aid from the efforts of others in that line."

This statement is plain, straightforward and convincing; and the writer is but one of many who believe that Mr. Pelton is entitled to the credit he has claimed. Moreover, an analysis of Mr. Pelton's statement is interesting. In discussing the matter, Mr. Pelton stated to two hydraulic engineers well known to the writer, that at one time, during experiments with a Knight wheel, the key securing the wheel to the shaft loosened, allowing the wheel to become laterally displaced on the shaft, so that the stream of water struck the buckets on their inner side; and that, as a result of this displacement, it was observed that the stamp-mill which the wheel was driving ran faster. This corroborates the statements of Mr. Pelton relative to Figs. 6 and 7, the first of which represents the Knight wheel at that time, while Fig. 7 shows the same bucket as it appeared after the Knight wheel had been displaced, as described. Of course the application of the jet in the manner shown in Fig. 7 would cause an end-thrust against the bearing on the jet-side of the bucket, to obviate which, the alternation of buckets shown in Fig. 8 would naturally suggest itself. As Mr. Pelton says, it would then be but a step in the evolution of the bucket

to combine the right and left buckets of Fig. 8 to the simple stream-splitting bucket shown in Fig. 9. It is of further interest to note that the arrangement of the buckets in rights and lefts, as Mr. Pelton states, antedates the distinguishing feature of the Tutthill water-wheel. Moreover, Mr. Knight says that he also experimented on buckets in rights and lefts early in the '70s, but abandoned the arrangement as being of no advantage to his form of water-wheel.

It seems that Professor Hesse has never made, of his own volition, serious claim to the invention of the divided bucket, but was drawn into the controversy by Mr. Pelton in the hope of disproving Mr. Moore's contention. The part that Professor Hesse took in the development of the divided bucket appears in a communication to Mr. Pelton dated May 19, 1897, in which Professor Hesse states that some time between 1865 and 1868 Mr. Moore called upon him (Hesse) and asked his advice as to the best water-motor answering the following conditions: high head, good efficiency, and such construction as to admit of its being built of wood at the mill, except flanges, shaft, and such light castings as could be readily transported on pack-animals, Professor Hesse's reply is best given in his own words:

"It is clear that, under the above conditions, only those water-motors deserve attention in which the energy of the water to be converted into work is received by the wheel in the form of kinetic energy. The tangential wheel with horizontal axis, a desirable condition, requires to be charged on its inner periphery, necessitating a large angle of entrance (the angle formed by the jet and the tangent to the wheel), causing a diminished efficiency and entailing, on account of limited space, a more costly construction. A wheel of the Jonval type with horizontal axis, the water flowing in planes parallel to the axis, seemed to answer best. It has, however, the disadvantages of being unbalanced: a serious point, considering the ever-shifting movement about the center, great number of revolutions, and large radius. Adding to this the necessity for a great number of buckets, with great length of water-way, to cause a proper discharge between the limited angles of entrance and discharge, it is clear that such a wheel would be heavy and of costly construction. I was aware of the fact that two such wheels, mounted on the same shaft, had been used heretofore to balance (see Fig. 10). Then it occurred to me that two such wheels might be placed together, so as to form one wheel, and one bucket out of every pair of buckets, reducing thus the entrance angle to 0, causing an increase of efficiency (Fig. 11). The jet entering in a direction tangential to the wheel is divided and discharges in two streams at the opposite sides of the wheel. Another advantage is to be found in the increased passage-way of the discharge-water, one on each side of the bucket, a fact which greatly lessens its weight and facilitates its free discharge. The best form of bucket could only be determined by actual tests and experiments, which were not made for lack of time. I furnished drawings for such a bucket to Mr.

Moore, and was afterwards informed by him that castings were made from this design, and were sent to a mine to be bolted to the rim of a wooden wheel. The result of the performance of the wheel, provided it was built, never reached me. Having never contemplated taking out a patent for what I considered so obvious an improvement, I lost sight of the matter from that time."

While it is cheerfully conceded that Mr. Pelton may have made his invention without cognizance of the work previously done by either Mr. Moore or Professor Hesse, the fact remains that his work was several years later than theirs. To a considerable extent, both Professor Hesse and Mr. Pelton rely on memory alone for dates; and in view of the documentary evidence produced by Mr. Moore, it is clear that Professor Hesse is in error in stating that Mr. Moore asked his advice on the subject "at some time between 1865 and 1868."

The writer is therefore convinced that Mr. Moore and Professor Hesse were the first to suggest the generally adopted form of the tangential-wheel bucket, containing the dividing-wedge to direct the flow of the water in reversing its direction.

But the statements of these three highly respectable men are given especially to show that different minds were working simultaneously upon the same problem. Did time and space permit, the efforts of many others in the same direction could be similarly detailed, conclusively demonstrating that the evolution of the tangential water-wheel bucket has had a history in which have figured not only the names of Atkins, Knight, Colman, Moore, Hesse, Tiscornia and Pelton, but also, and largely coincident with them, those of James Patterson, Louis Biggio, John B. Pitchford, S. L. Berry, Francis M. F. Cazin, Daniel Hug, W. G. Dodd, the Risdon Iron-works (San Francisco), and the early wheels of D. Donnelly of Sutter Creek, and Watson of Nevada City, Cal., as well as James Leffell & Co., the Risdon Iron-works, and the Abner Doble Co., with their respective Cascade, Risdon and Ellipsoidal wheels respectively. Still other wheels might be mentioned, such as the Kale, Ridgway, Bookwalter and Tutthill.* The forms of the

* See the several United States patents, as follows: Biggio, No. 356,977, February 1, 1887; Pitchford, No. 485,477, November 1, 1892; Berry, No. 493,239; March 14, 1893; Cazin, No. 578,812, March 16, 1897; Hug, Nos. 576,728 and 576,849, February 9; 1897; Dodd, No. 401,484, April 16, 1889, and 454,638, June 23, 1891; Risdon Iron-works, No. 599,845, March 1, 1898, and design patent

Pelton and Dodd buckets are shown in Figs. 12 and 13 respectively.

Of these buckets, the Biggio is the only one that does not claim distinct advantages from the use of a sharp central and radial division which splits the stream. In the Biggio bucket, which is shaped something like the letter "W," made with low rounded turns instead of angles, the central ridge is but a partial division. The Pitchford bucket contains a sharp, radial dividing-wedge, and the front or outer lip of the bucket slopes towards the direction of rotation, so as to prevent this outer lip from striking the jet when the bucket enters the stream. This patent also provides a means whereby "the true apex of the bucket" may be centered in the stream. The Berry patent (Fig. 15) contemplates a divided bucket of such shape as to present, in the plane of rotation, surfaces at right-angles with the stream, permitting a free discharge tangential to the wheel, and avoiding disturbance of the stream on entrance. This the patentee endeavors to obtain through the use of convex instead of concave surfaces for the faces of the buckets which are presented to the jet.* The Cazin patent partakes of Pitchford's idea, in that its bucket is intended so to enter the jet as to prevent the slapping of the stream by the lip of the bucket. Cazin professes to accomplish this by projecting the peripheral lip or edge, still using radial wedges (as do all buckets other than the ellipsoidal, which will be described later). The Cazin bucket divides the stream in two entirely distinct planes, viz.: first in a plane parallel to the axis of the wheel's rotation, and, second, in a plane at right-angles thereto, or in the plane of the wheel's rotation. The Cazin wheel, moreover, is so designed that the entering lip, which is transverse to the plane of rotation, first enters the stream, but the end of this entering lip travels a path of greater radius than that which is covered by the bucket proper; therefore as soon as it enters the stream the jet is deflected, so that it misses the bucket next in advance of the entering one. Cazin thus not

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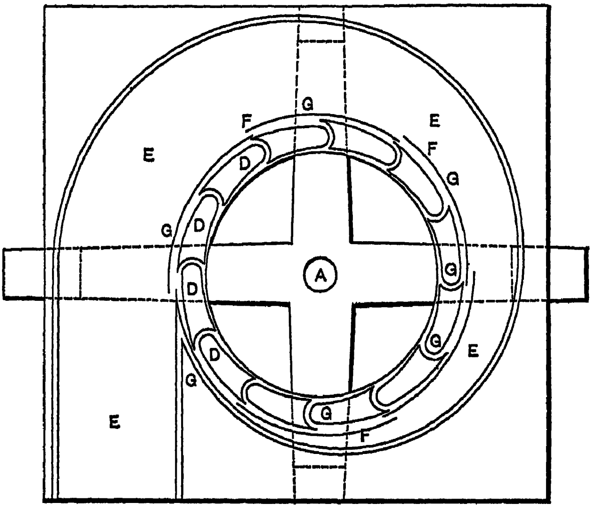
No. 26,568, January 26, 1897; Donnelly, No. 255,259, March 21, 1882; Abner Doble Co., Nos. 619,148 and 619,149, February 7, 1899, and No. 633,184, September 19, 1899; Ridgway, No. 453,419, June 2, 1891; Bookwalter, No. 469,959, March 1, 1892; and Tutthill, No. 534,772, February 26, 1895.

* *Cassier's Mag.*, vol. v., p. 125.

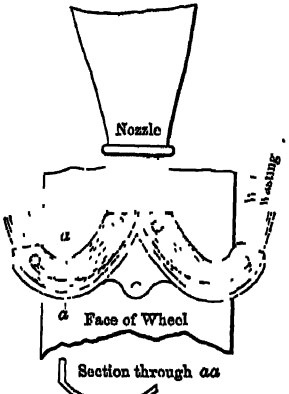
only loses the direct effort of the stream, but, by missing that bucket entirely, the possible reactive effect of the water thus deflected is lost. The same is true, however, in smaller degree, of practically all the other types of buckets having straight entering lips, as will be more fully shown further on. The Pelton, Risdon, Hug, Cazin and Dodd buckets are characterized by the broad edge which forms the entering lip of the bucket. This lip, in conjunction with the splitting-wedge, exerts a twofold influence upon the stream; first, the entrance of the bucket into the jet causes the stream to be split by the entering lip in a plane that is axial to the wheel; secondly, as the portion of the jet which is diverted into the bucket encounters the splitting-wedge therein, the water is again divided, and, instead of pursuing its natural flow, is ordinarily forced to follow a path provided for it. These lipped buckets are, therefore, objectionable in several respects. They not only divert the stream from its natural course while the lip is passing through the stream, but they also break up that part of the stream which is entering the buckets, setting up in the water a violent swirling action, which prevents its smooth flow through the buckets. This not only cuts the buckets, but also destroys the best results of reaction of the water, and causes an additional loss of efficiency through the reaction of part of the discharged water against the back of the next following bucket (see Fig. 14). The Dodd bucket, which has been acquired by the Pelton Water-wheel Co. and, in a slightly modified form, is gradually displacing the original form of Pelton bucket for high heads (the form always meant in this paper when the "Pelton" bucket is named) partly obviates the inherent disadvantages of the straight-lipped bucket by giving the entering lip a curved-in form, which more quickly envelopes the stream than it is possible to do with a straight edge. The Ridgway, Bookwalter, Kale, Watson, Tutthill and Cascade wheels form a class by themselves, in that the buckets are placed alternately on the sides of the wheel rim, that is in rights and lefts. Ridgway placed two directing ribs equi-distant through the radial line of the bucket, the shape of which bears a strong resemblance to the cups used on belt elevators for hoisting grain. The Bookwalter bucket had a simple cup-shape, and was so arranged on the periphery of the wheel that but half of the jet

FIG. 1.



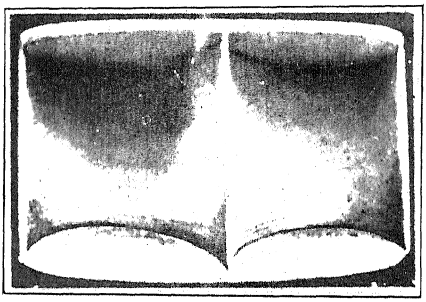
Outline Drawing of the Atkins Wheel.

FIG. 2.

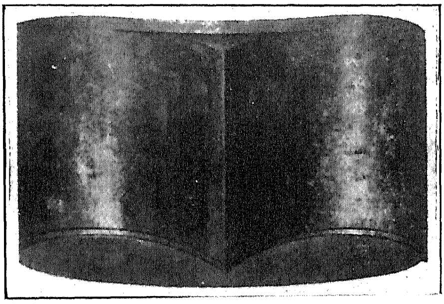


Copy of Moore's Original Sketch (omitting manuscript directions at top and bottom).

FIG. 3.



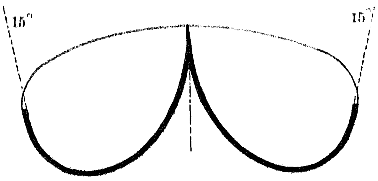
Front View.



Rear View.

Pattern of Original Buckets made by Risdon Iron-Works for G. Tiscornia.

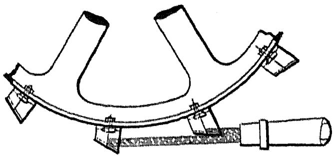
FIG. 4.



TRANSVERSE SECTION, HALF SIZE.

Moore's Bucket.

FIG. 5.



MANNER OF MOUNTING THE BUCKETS.

Moore's Wheel.

FIG. 6.

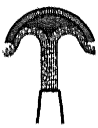
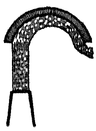


FIG. 7.



Pelton's Sketches.

FIG. 8.

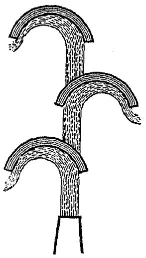
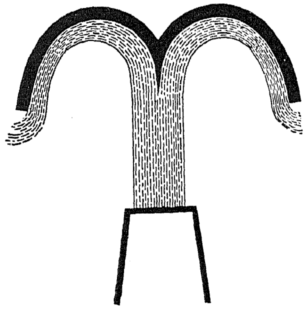


FIG. 9.



Pelton's Sketches.

FIG. 10.

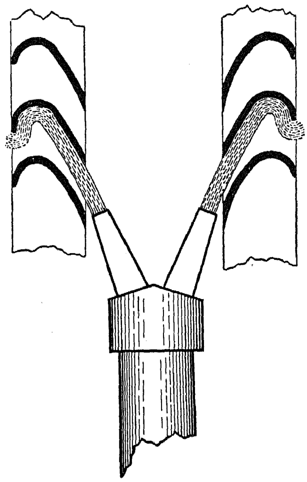
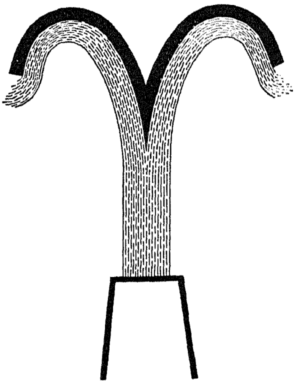
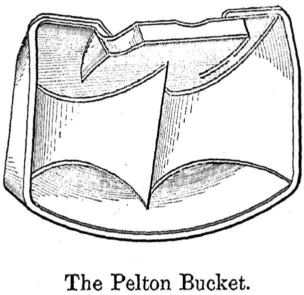


FIG. 11.



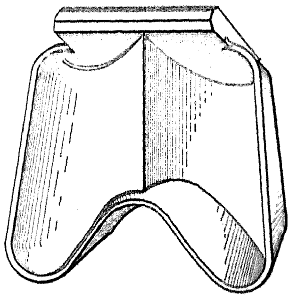
Hesse's Sketches.

FIG. 12.



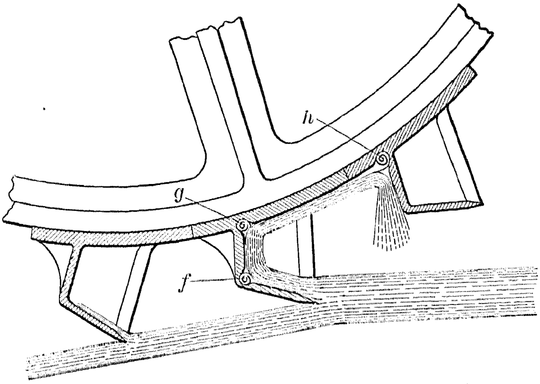
The Pelton Bucket.

FIG. 13.



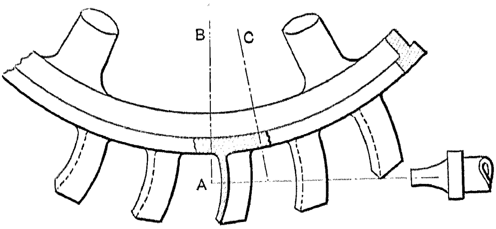
The Dodd Bucket.

FIG. 14.



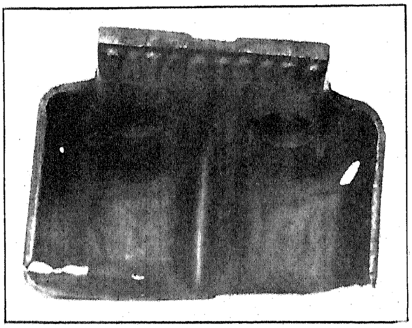
Illustrating Erosive Process and Deflection of Jet.

FIG. 15.



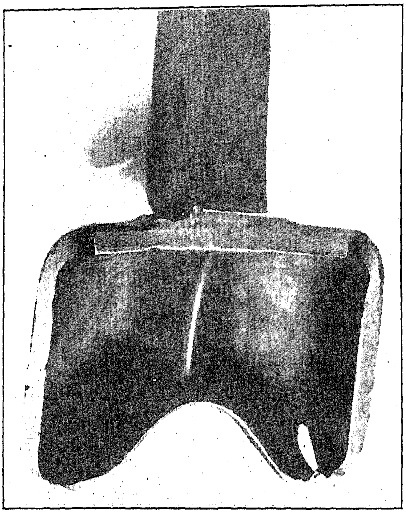
The Berry Bucket.

FIG. 16.



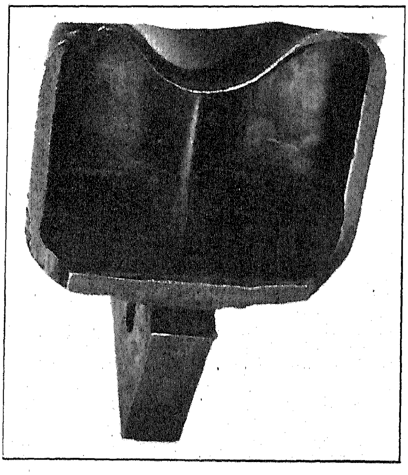
A Perforated Pelton Bucket.

FIG. 17.



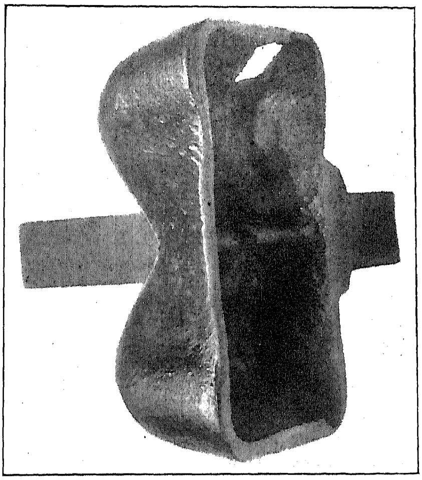
A Perforated Dodd Bucket.

FIG. 18.



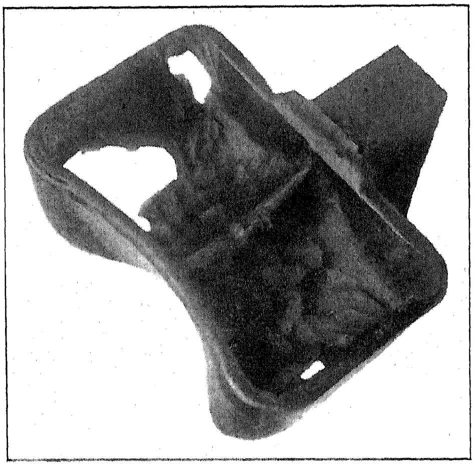
A Perforated Dodd Bucket.

FIG. 19.



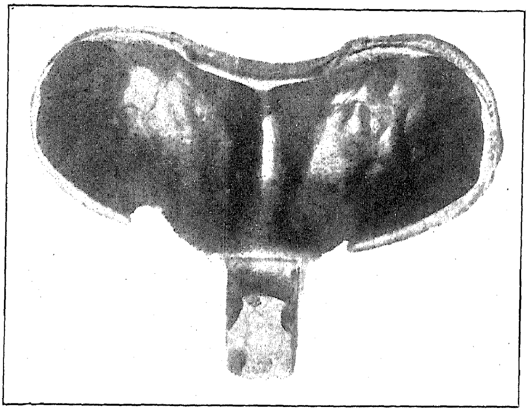
Showing Wear on Outer Lip of a Dodd Bucket.

FIG. 20.



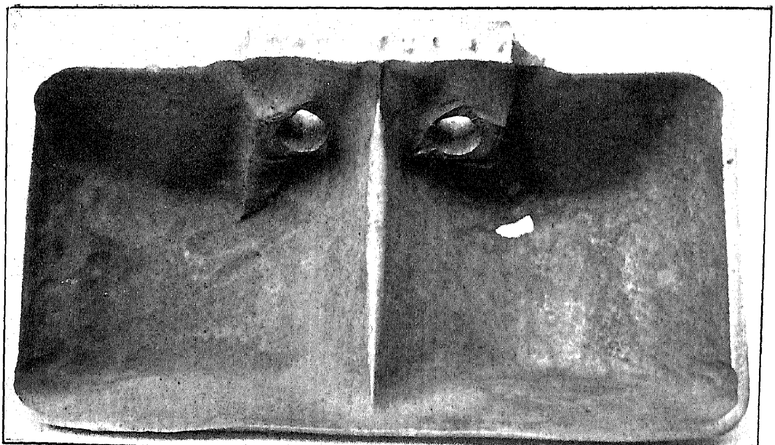
A Perforated Dodd Bucket.

Fig. 21.



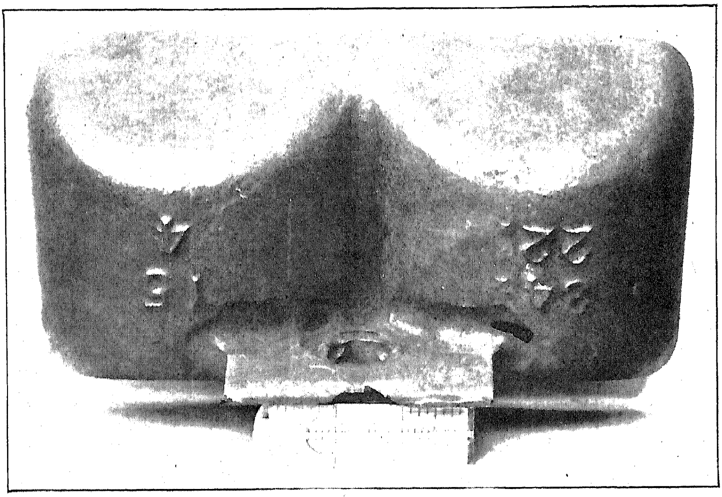
A Modified Dodd Bucket Showing Whirlpool- and Eddy-Action.

Fig. 22.



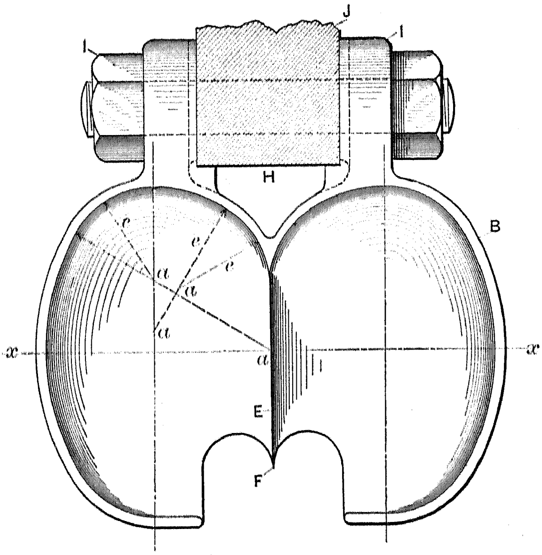
Front View.
A Pelton Bucket used in Gritty Water.

FIG. 23.



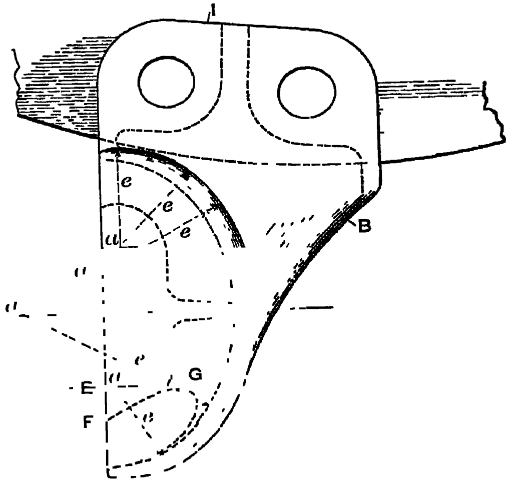
Rear View.
A Pelton Bucket used in Gritty Water.

FIG. 24.



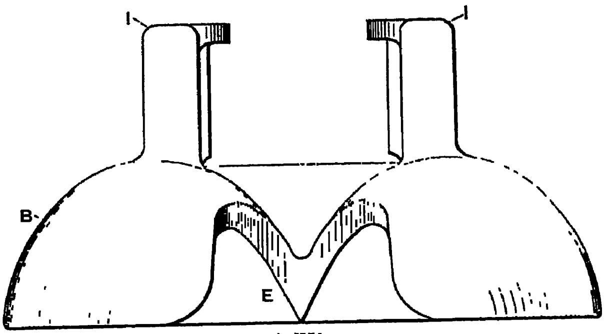
Face View.
The Ellipsoidal Bucket.

FIG. 25.



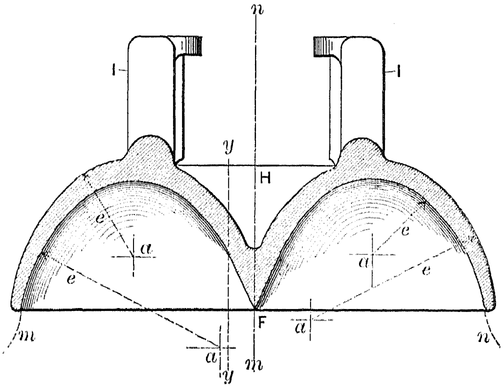
Side View.
The Ellipsoidal Bucket.

FIG. 26.



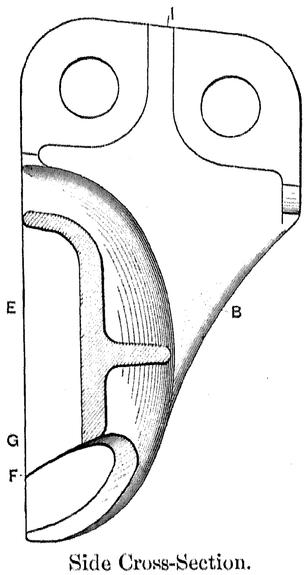
End View.
The Ellipsoidal Bucket.

FIG. 27.



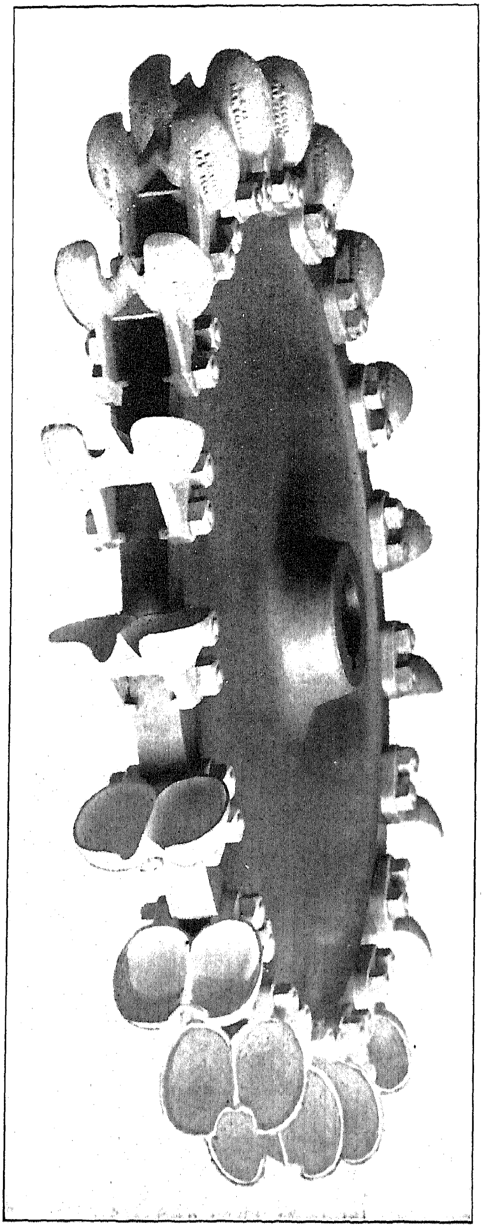
Front Cross-Section.
The Ellipsoidal Bucket.

FIG. 28.



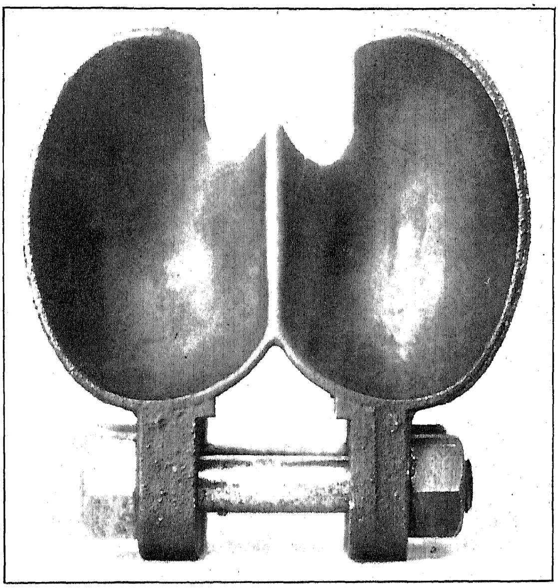
Side Cross-Section.
The Ellipsoidal Bucket.

Fig. 29.



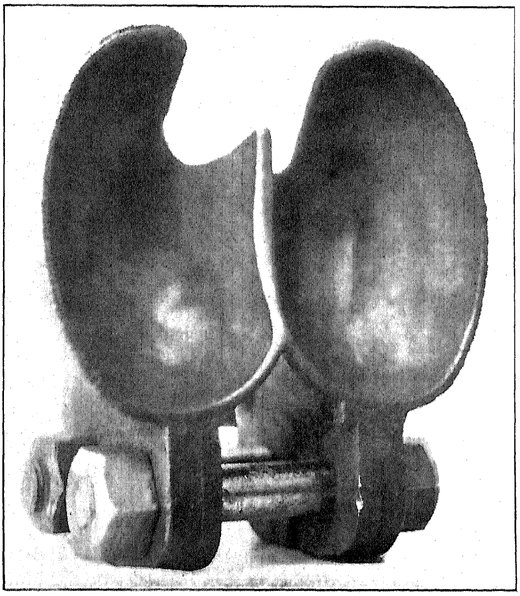
A Finished 1000 Horse-Power Ellipsoidal Wheel.

FIG. 30.



Ellipsoidal Bucket after 12 Months' Use, 400 feet Head Gritty Water.

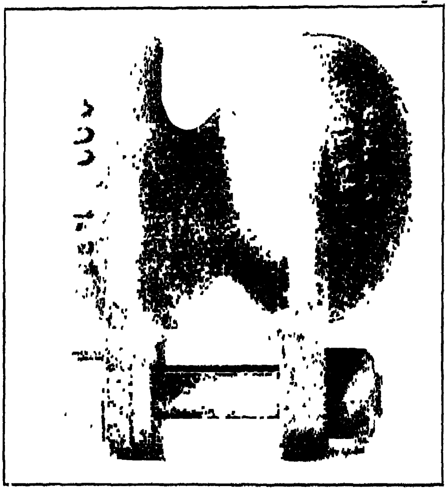
FIG. 31.



Ellipsoidal Bucket after 12 Months' Use, 400 feet Head Gritty Water.

entered each bucket; that is, the inner edges of the alternate buckets did not overlap. The difference between the Bookwalter and the Tutthill wheel, therefore, rests mainly in the fact that in the Tutthill wheel the entire jet as a unit goes into the buckets. In the Watson, Kale and Cascade wheels, the central dividing edge is placed around the periphery of the wheel, in the plane of its rotation, and central to the jet; and on the opposite sides of this dividing edge the buckets are placed in rights and lefts. In the Kale wheel the buckets are but straight paddles as in the familiar flutter-wheel, while the other wheels use cup-shaped buckets.

FIG. 32.



Ellipsoidal Bucket after 12 Months' Use, 400 feet Head Gritty Water.

An ideal bucket for a tangential water-wheel, that is, a bucket from which would be secured the greatest effective power for the energy applied, would receive the stream of water in a solid condition, reverse its direction without breaking it up into spray, and discharge it along natural lines in an even flow over the whole bucket-surface. Its form would be such that the plane of the bucket, say, at the edge of the dividing-wedge, would always be perpendicular to the direction of the stream. Finally, the force exerted by impact and reaction from the stream would be equal, whatever angle the plane of the bucket might bear to the axis of the jet. Of

course every effort should be made to minimize the friction between the stream and the surface of the bucket (a principle opposed to the idea which prevailed in the design of the Biggio bucket); to give ample clearance between the buckets, that they may discharge freely; to give each bucket the longest possible arc of contact with the stream; to avoid beating or slapping the stream with the lips of the buckets; and so to dispose the buckets that each, as a whole, will enter and leave the stream with the utmost quickness.

The buckets of the most familiar forms split the stream on entering it, in two planes, viz.: the entering lip splits in the plane transverse to the wheel's rotation, while the dividing-wedge in the center of the bucket splits the stream in the direction of the wheel's rotation. The transverse splitting is both unnecessary and undesirable. A bucket which will *not* split the stream transversely, and which is of such a shape as to preserve the perpendicular position relative to the stream above specified, is found in the ellipsoidal type, which has no entering lip, and the shape of which is described from true hydraulic curves. Interesting illustrations of the above propositions are furnished by buckets taken from wheels which have been run with water containing sand, grit or "slickens." One of them, of the Pelton type, is shown in front and back views, respectively, in Figs. 22 and 23. Under these conditions, the faces of the buckets are badly worn from striking against the jet; the corners within the buckets are deeply cut or perforated, according to the time of service (in this case, 8 weeks); and the inner corner of the back of each bucket, is similarly worn and perforated from the backward discharge of the immediately preceding bucket. These erosions are all due to the swirling of the water because the bucket is so formed as to prevent proper discharge. The reason will be clear from an examination of Fig. 14. The jet, striking on the inner side of the face of the bucket, glances off the surface at an angle equal to that of incidence; and this action occurs at three points within the bucket, namely, on its front, bottom and rear faces, as is clearly shown by lines of erosion cut by the sediment carried in the water. As an inevitable consequence, a swirling action will take place at the corners *f*, *g* and *h*, Fig. 14, resulting in great loss of energy and the eventual perforating of the bucket at these points.

Buckets made on true hydraulic lines show no pitted erosion; such wear as occurs in them is uniform and even throughout. Figs. 30, 31 and 32 represent an ellipsoidal bucket which has been in continuous service for twelve months under a head of 400 feet at the Dreisam mine, W. Moorehead, Superintendent, Soulsbyville, Tuolumne county, Cal. Here the water contains much grit; from 2 to 3 tons of sand per day passing through the pipe-line and being shoveled out from the tail-race daily. Fig. 30, a face-view, shows the smooth uniform wear on the active and reactive faces of the bucket, which are entirely free from erosions such as would occur from swirling water. This also indicates a uniform discharge of the water around the entire discharge-edge of the bucket. Fig. 31, likewise a face-view, shows the wear on the dividing-wedge, which, being greatest at the middle of the bucket, demonstrates that the maximum effort of the water is at this point, where it would produce the best results. Fig. 32 is a back-view of the same bucket, showing absolute freedom from any impingement of the water on the back of the bucket, the skin of the casting remaining as it originally left the mould. The smooth wear of this bucket, with the total absence of any eddy-action, is believed to prove the correctness of the hydraulic curves, and likewise of the theories on which the design of the bucket is based. Note in Figs. 30 and 31 the slight depression in the center of each bowl of the bucket. This depression is directly opposite the reinforcing ribs on the back of the bucket (see Fig. 32); and the additional wear at this point was caused by the difference in the hardness of the casting. The metal where the reinforcing rib joined the bucket, having more body, cooled more slowly in the mould than the other and thinner parts of the bucket, causing the metal at this point to be slightly softer; whereas the iron in the thin section of the bucket showed a tendency to chill, and thus permit the greater erosion at this point. The shape and location of this depression clearly prove this.

To appreciate these points fully, it must be borne in mind that, unless the stream enters the buckets from their sides, simple cup-shaped buckets, without dividing-wedges, permit the accumulation of dead water at the base of the cup. The splitting-wedge was devised to do away with this dead-water,

and to extend an invitation to the live water to turn its direction back upon itself, that it might, by reaction, impart further energy to the wheel. The invention of the dividing-wedge, therefore, constituted a long step in the right direction. Again, the maximum torque which a tangential wheel, held stationary, will exert, will be given when the direction of the jet is, as stated, perpendicular to the plane of the bucket; that is to say, the angle of the maximum effort which a jet can exert is tangential. There are two ways by which this condition may be satisfied, one of which is impracticable, while the second is simple and effective. The feathering paddle-wheel offers the key to the first solution, for, as it always enters the water at right-angles, it would keep the plane of a water-wheel bucket perpendicular to the axis of the stream during the arc of contact. But the application of this device to tangential wheels, with their high rotative speeds and centrifugal force, presents mechanical difficulties which preclude all hope of success. The second solution is found, deeply veiled, in the Berry bucket (Fig. 15), the reciprocal of which furnishes such hydraulic curves for the faces of buckets as will give a smooth and uniform distribution of forces over practically the entire surface of the bucket, regardless of its position in the arc of contact with the stream. This feature is more fully developed in the ellipsoidal type, to be further discussed below.

The ideal bucket should possess some other important features. The manner in which the jet is brought into contact with the bucket is of paramount importance. All will concede that the stream should enter the bucket in a solid condition; in other words, it should be disturbed in the least possible degree. The entrance lips in use are either straight or incurved. The great majority of buckets have the straight lips as in the original Pelton, the Risdon, Hug, Cazin and other well-known forms. The main example of the curved entrance lip is found in the Dodd wheel. The ellipsoidal bucket has no entering lip. I cannot but believe that, of the two latter, the last is the more efficient, for the reason that the Dodd bucket is so formed that the stream is split, before entering the bucket, by the in-curved lip, while in the ellipsoidal bucket the solid stream is not split or otherwise interfered with, in any manner whatever, until after it meets the dividing-wedge.

In fact, the only contact of the ellipsoidal bucket on entering the stream is with the dividing-wedge. A lipped bucket tends to break up the stream and to deflect it during the transit of the lip, thus setting up swirling actions which interfere seriously with the reactive effect. It tends, moreover, to divert the stream outwardly, because of splitting it as by a wedge having an edge which is axial to the wheel; and thus it splits the stream transversely (see Fig. 14) before the wedge in the bucket has an opportunity to split it radially to the wheel and reverse the direction of the water. Finally, in the ellipsoidal bucket the stream is only divided in the plane of the wheel's rotation, and thus separated into only two equal parts, each of which flows over the [illegible]-curved faces in the bucket, reversing the direction of flow without disturbance of shock, and avoiding the eddy-currents set up where an end lip is used. Buckets of the entering lip type first shave off the stream in thin slices, each slice being again divided by the central dividing-wedge, this additional disturbance to the stream preventing the smooth flow of the water through the bucket, which is essential to high efficiency.

The condition which the ideal bucket imposes, that the water shall follow along natural lines and receive an even flow throughout the whole surface of the bucket, is one which has not been satisfied by any of the forms of tangential wheels with which the engineering public is most familiar. Proof of this, as already observed, will be found in a study of buckets of those makes that have been in use for some time under high heads of water containing slickens or sand. Such buckets as those illustrated in Figs. 16 to 22 inclusive, show strongly marked erosions from whirling water within them, and demonstrate that nature often ignores entirely those paths which the designers of the buckets had selected as proper directions of discharge, and that the water takes a radically different course therefrom, as is proved by the erosion. In some cases of operation under comparatively moderate heads, this erosion is so great in the best known type of bucket as to perforate the bucket in from six weeks to two months, requiring new buckets throughout the wheel. One of these perforated buckets is shown in Figs. 22 and 23.

An analysis of some specific instances will be of interest.

In Fig. 16 (Pelton bucket) the perforation and erosion at the junction of lip and bucket-face may be noted. In Fig. 17, a small bronze Dodd bucket has its face or outer surface so formed that, in dividing the stream approximately at right-angles to the plane of rotation, it continually strikes the stream with this outer face, as is evidenced by much wear, and a perforation which can be clearly seen thereon. Such evidence demonstrates that there is a retarding influence to the passing of the buckets into the stream, as will appear on examination of Fig. 18. If we consider this in connection with the fact that the wheel from which the bucket shown in Fig. 17 was taken contained forty such buckets and ran at about one thousand revolutions per minute, giving, therefore, forty thousand impacts or disturbances per minute to the stream, we can appreciate the fact that this continual slapping in the stream would necessarily have a tendency to seriously break it up. More than this, it deflects the stream so that much of it entirely misses the bucket in advance of the bucket entering the stream (see Fig. 14).

In Fig. 18, the inner surface of a Dodd bucket is also much eroded in such a way as to disprove the theories formerly advanced concerning the discharge of water from buckets of this type. The erosion in this case shows conclusively that the greater discharge of water was from the upper and lower corners, or the inner and outer ends of the buckets; in fact, one outer end of the bucket shown in Fig. 17 is entirely cut through, while the side of the bucket whence the discharge was supposed to have taken place shows no appreciable wear, but retains practically its original thickness. The metal is also very much worn away from the inner to the outer end of the bottom of the bucket. Fig. 21 shows the whirlpool-action of the water in a modified Dodd bucket. These erosions, and the others shown, were clearly due to violent whirlpools in the water, and demonstrate that the lower end of the bucket divides the stream into horizontal strata, so as to break up and destroy its solid condition. Instead of the bucket being acted upon by solid water, it is therefore in reality filled up with a swirling mass, which causes the loss of the best effects of reaction, and reduces the efficiency very materially. Such specimens of worn water-wheels are by no means rare. As a rule, the sides

which are supposed to form the discharging- or reacting-faces show very little, if any, wear, while the bottoms and ends, and particularly the corners, show the most wear, and often complete perforation, as the effect of the eddying currents (see Fig. 18). In the Dodd bucket, shown in Fig. 19, the outer lip is much worn from striking the stream; whereas the inner surface of the lip shows no wear whatever, although directly on the other side of the wall from the preceding. The conclusion is inevitable that, had the end of this bucket been left open, the energy of the water which was wasted in wearing the outer end would have given useful effect on the reactive faces, to say nothing of the advantage that would have followed from not breaking up the stream many thousand times per minute.

It is worth noting that the builders of these wheels designed the curves and shapes of the buckets with the wheel stationary, and did not take into consideration its relative velocities and the resulting angles of the buckets to the impinging jet. This is shown by the fact that all existing drawings detailing the application of the jet to the bucket show the jet impinging in the middle of the bucket, and divided into two semi-circular sectional streams of water, flowing over the faces and discharging from the sides of the buckets. The divided water is shaded in such drawings, to indicate its semi-circular section, whereas in reality the impingement of a stream of water against a surface or inclined plane causes the water to flatten and spread. This condition not being taken into consideration, the designers overlooked the requirements of free discharge. In reality, the buckets move rapidly in relation to the stream; but in designing the curves of the buckets they have considered the actions and reactions of the stream within the bucket to be the same as if the bucket were stationary. On the contrary, the problem of the resolution of forces of the tangential wheel changes with each and every change in the position of the bucket with reference to the stream. The first authentic record of a thorough appreciation of these variations in forces which result with each change in the position of the wheel appears in the Berry patent (1893). If it be granted, as perhaps it may be, that some of the buckets produced by well-known manufacturers are correctly designed as to impulse and reaction at one given point of impingement—say, when the axis of the stream

is perpendicular to the plane of the base of the bucket—then it unquestionably follows, from the equally indisputable fact that this angle and the bucket-curves are constantly changing during the period of contact between stream and bucket, that the design of the bucket, when in all other positions than that of the perpendicular stated, must vary correspondingly from a condition of slight error to one of absolute wrong. So marked is this error, that one who studies the situation in all of its many phases can but wonder that the most familiar types of tangential wheels embodying these defects in design should be possessed of a laboratory efficiency of over 70 per cent. (which, however, they seldom realize in actual practice). The idea which prevailed in the design of the Berry bucket was, that the axis of the stream should be normal to the surface of the bucket, whatever its position within the arc of contact with the stream. To accomplish this, buckets of convex forms, of a carefully calculated curvature, were used. Just why this bucket has never seen commercial usage (unless it be that it has gone the way of many other good and useful inventions, and has been "shelved" by its owners) is not apparent at first; but becomes so on reflecting that, while the axis of the stream may be perpendicular to the tangent of the surface of the bucket, the stream itself, having breadth and consequently bulk, can never be such. In other words, the axis of the stream is an imaginary line without cross-section; the stream has cross-section; hence the line forming an outer confine to the stream, though parallel with the axis, will not be normal to the surface of the bucket. Herein rests the vital point pertaining to the Berry bucket in a commercial sense—the theory of the bucket is correct, but practically it is without distinguished utility, for the reason stated.

The theoretical feature of the Berry bucket which has been discussed, marked a distinct innovation in water-wheel practice, when its inventor declared that "a thin edge entering the stream transversely is better than any entrance made at an angle (*i.e.*, as in the Risdon, Pelton, Hug, Dodd, Cazin, Tutthill and Cascade buckets) or any of the forms hitherto adopted, because not only must disturbance be taken into account, but also the effect produced by the diverted water while the stream is being severed. (See Fig. 14.) The two things must be con-

sidered together; the value or effect of disturbance is much more complex than the losses due to misdirected water." In this Mr. Berry was quite correct; but, to go a step further, it is obvious that if the transverse splitting of the stream could be avoided, that is, if the bucket could enter the jet without splitting it transversely; if the first and only splitting of the stream could be that caused by the radial dividing-wedge within the bucket; and if the curvature of this bucket could be such that the resolution of the forces exerted by the stream would always be in lines tangential to the surface of the dividing-wedge, whatever be its position in the arc of contact with the jet, then the highest possible efficiency will have been attained. These revolutionizing features are accomplished by the new form of ellipsoidal bucket, which has been brought out within the past year. The writer is therefore constrained to say that the latest and most important change and improvement in tangential water-wheel practice, since the development of the Colman-Moore-Heese buckets, has been the recent adoption of what may be called true hydraulic curves for the faces of the buckets, and the division of the jet vertically, or radially and in one plane only, *after* its entrance within the bucket.

The first of these features has, by some strange oversight, escaped the attention of engineers. For fifty years past it has been a prominent and even essential feature in turbine-practice, and indeed in all of the refined type of water-wheels wherein the water was reversed in its course over the faces of the buckets; but it has not been considered, or at least has not been applied, in tangential-wheel practice, up to the time when the buckets shown in Figs. 24 to 28 were adopted for wheels installed for operation in large units under high head. Previously the faces of the buckets had either been true curves, or developed curves that did not conform to the hydrodynamic conditions demanded.

As the ellipsoidal form has received United States letters-patent,* passed after a crucial investigation of the subject by the officers of the bureau, I will, for explanation, quote from the descriptive portion of the Specification, merely changing Fig. numbers to conform to this article:

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* Nos. 619,148 and 619,149, Feb. 7, 1899; and No. 633,184, Sept. 19, 1899.

"The buckets are of a double-trough form, having an elliptical contour, as shown in Fig. 24, the transverse curves at the center terminating in an acute wedge E that splits or divides the stream C into two equal parts that are diverted by this wedge, and the curves at its sides each way into the troughs forming the sides of the bucket. The form of the buckets in two planes is indicated in Figs. 25 and 26, the face or rim in Fig. 24 presenting ellipsoids developed from radii approximately, as shown, so that the curves traversed by the water after its impingement are the same in whatever direction it may flow after impingement.

"In my former application for letters-patent, the buckets, while the same in general construction and disposition as those herewith illustrated, were formed with straight sides and bottoms, and with true curves only, so the water preserved during its flow over such surfaces a uniform velocity. Subsequent experiments proved that a greater efficiency could be obtained by means of modified curves of an ellipsoidal form, as herewith illustrated, and known as the hydraulic curves for such surfaces.

"These curves, as shown in the drawings, are generated from centers marked *a*, by the radii *e*, and are taken from practice, and one in which the axes of the ellipse from which the curves are generated are as nearly approximate as common practice admits. In other words, variations from the form shown are usually in the direction of an ellipse with greater variations between its major and minor axis, depending upon the size of the jets or streams and the size of the buckets in relation thereto.

"This ellipsoidal form of the acting surfaces which guide the flow of water in the buckets produces, as will be seen, a cumulative degree of deflection until the direction of flow is reversed—maintaining the velocity of the water with the least retardation and thus securing the maximum reactive effect, avoiding irregular flow and gaining a complete clearance of the water from the bucket after its energy is expended, also permitting a greater velocity of the wheel-rim in proportion to the head or pressure of the water and increasing the efficiency developed by the wheel.

"The dividing-wedge E is not external to, but within the bucket, and has in the rear, or from its point of entrance F, an upward or retarding angle G, so the point F, or extreme of the wedge, enters the jet or stream C in a manner to avoid disturbance of the water which had not previously come in contact with any part of the bucket. Below or beyond the end F of the wedge E the end of the bucket is cut away, as seen in Figs. 23, 25 and 27, so the sides will not touch the impinging stream, but nevertheless furnish at each side, in proper position, the required surface for reactive discharge, which takes place approximately on the lines *m n*, as indicated in Fig. 27.

"In this manner there is no division or disturbance of the stream except in the plane of the wheel's rotation, and it is to avoid this that the ends of the buckets are cut away at the bottom, omitting the usual end wall, or other obstruction that enters and cleaves the stream transversely to the dividing-wedge E, and directs it in various and devious ways, before it is divided by this wedge E."

Fig. 29 shows a wheel of this type having a capacity of 1000 H. P.

The theoretical deductions respecting this ellipsoidal configuration of the bucket faces, and the cutting away of the skirts of the buckets, so that the stream of water is divided in one

plane only, have been fully verified by experiments under heads from 35 to 1300 feet; and the efficiency attained is such that further research as to the shape of tangential buckets gives but little promise of better results in that direction. I am, however, of the opinion that there are other means of adding to the already high efficiency of tangential water-wheels; but experiments made thus far, although extensive, are not in a form to be presented in the present paper. They will no doubt furnish subject-matter for a future paper, dealing with conduits and the internal conditions of jets issuing under high pressure. I regret that this subject could not be brought into the required form in time to constitute a part of the present paper; but it must be remembered that hydraulic phenomena developed under high pressures are very imperfectly understood, and that, so far as dealt with in practice, the problem is mainly confined to the Pacific coast, and the usual aids and references available in other cases are wanting.

I will remark again, in conclusion, that the development of open or impulse water-wheels, like all other mechanical implements, had to pass through a period of evolution, and the results obtained are the cumulative work of many men.

Having thus considered the history and development of the tangential wheel, it will be pertinent to discuss briefly its adaptability in the engineering field. The tangential wheel is especially fitted to certain classes of work. Its extreme simplicity, together with its low first cost, coupled with the fact that modern wheels are of very high efficiency (over 80 per cent.), render it suitable for such installations as require absolute reliability. As compared with the turbine, its first cost for heads of more than 50 feet is very much smaller, and its cost of maintenance is but a fraction of that of the turbine. In addition to the fact that its initial efficiency is superior to that of the turbine, it also maintains its original high efficiency throughout its life; whereas that of the turbine constantly decreases as the wheel wears in the casing, allowing the water to pass by, instead of through, the wheel. The variation in design permissible in turbine-practice is quite limited, as regards speed and power, by reason of the excessive cost of turbines of large diameter; whereas with the tangential wheel it permits of a very wide and free scope to the designer, wheels having been made in California from 3 inches

to 30 feet in diameter, and to work under heads ranging from 35 to 2100 feet, and under speeds ranging from 65 to 1150 revolutions per minute. Moreover, there have been made a number of single wheels having a capacity of not less than 1000 horse-power each.

But the tangential wheel, as a means for effecting the industrial distribution of power, is brought forward not as a rival to the existing systems, but rather as a complement to them. On the Pacific coast, in the Orient, and in Central and South America, where the available water-powers are at high head, the tangential wheel is naturally at home. Its usefulness, however, is not limited to the field where these conditions exist in nature. For certain classes of work it can advance equally strong claims, even where it is necessary to artificially produce these high pressures by the use of modern high-duty, steam pumping-engines. This may seem rather dangerous ground; but when we consider the very high duty that can be secured with modern pumping-engines, coupled with a rotary motor, which will give an efficiency exceeding 80 per cent. (including the losses in a properly-designed system of distribution), and that we can rely on getting these efficiencies even in units of small size, we may appreciate the fact that the tangential wheel can honestly make a strong demand for recognition. As an example, consider the power-distribution in a modern steel- or iron-mill, where the power required by the individual machines is in large units. The advantages to be gained by the installation of a tangential-wheel system for work of this character may be summed up as follows:

The concentration of the boilers and pumping-engines in one central pumping-plant, which would be naturally installed in the most favorable location. Modern pumps can easily be designed to pump against a pressure of 300 to 500 pounds per square inch. From this central pumping-plant the distribution would consist of pipes or mains, from which the whole system would be supplied. Return-conduits could be provided to bring the water back to the pumping-engines wherever it was desired to use it over and over again. This would remove from the mills the large engines which are required to drive the heavy machinery, economizing the room which the engines would occupy, and saving the cost of their massive foundations—inas-

much as a water-wheel of sufficient power to replace one of these engines would occupy about the same space as the fly-wheel of the engine. Being exceedingly simple and almost indestructible, the tangential wheel would save the cost of maintenance and the annoyance of break-downs of these large engines, the service of which is much impaired by the unfavorable conditions under which they labor. Moreover, the net efficiency of the water-wheel plant would be much superior to that of independent engines, besides doing away with troublesome and inefficient steam-pipes and the separated batteries of boilers. As indicated, the tangential wheel can be built of any desired horse-power capacity; also, by making the buckets of double form, a single wheel with a double nozzle is adaptable for work requiring reversing-engines; and, what is of great importance, the reversal of these wheels can be quite sudden, because as the jet is applied to the rim of the wheel its moment of inertia in reversing will be taken up by the water, without imposing the serious strains that a fly-wheel is subjected to when reversed. By using the newer type of regulating nozzles, absolute control can be had, not only of the speed, but also of the power of these wheels; and, in addition to this, the nozzle and wheel can be so designed as to keep available a large increase of power over the normal, should it be required—as, for instance, when a "cold heat" is going through the rolls. With these newer combinations, the efficiency of the wheel over a very wide range of power is exceedingly high; that is, the efficiency-curve of the wheel will show exceedingly high results, even when the power called for is only a fraction of its capacity. For handling auxiliary apparatus, the wheels are much superior to the usual small engines, or even to electric motors, for the reason that the water-wheels will stand all manner of abuse and neglect; they can be controlled absolutely, reversed almost instantly, are not subject to break-downs and other annoying characteristics; and, in addition, they are less costly to install. The more extended use of hydraulic apparatus would not be an innovation in a modern mill, as I presume there is no mill of any great consequence which has not an extensive hydraulic plant used for operating reciprocating motors—that is, presses, shears, lifts, manipulators, and the controlling apparatus for Bessemer converters. It would therefore be a concentration of

plant; and experiment in this line, to demonstrate thoroughly the efficiency and reliability of the proposed hydraulic system of power-distribution by tangential water-wheels, may easily be undertaken simply by connecting such wheels for operating the auxiliary apparatus referred to, with the mains of existing hydraulic systems.

POSTSCRIPT.

After considering the difference in design, and also in wear and erosion, of the buckets of the several types, as compared with the ellipsoidal bucket, it is of interest to note the higher efficiency in the practical results ascertained from the wheels. Relative-efficiency tests are the most reliable, and really give the best insight into the relative values of the several buckets. The most recent, and perhaps the most interesting, of such comparative tests is one recently conducted in the power-plant of the San Joaquin Electric Company, Mr. J. J. Seymour, President, of Fresno, California. This case was particularly interesting, owing to the fact that the wheels were running under a head of 1410 feet, the horse-power developed being approximately 500 H. P. per wheel, the plant having been designed to be of high class, and in fact representing the best efforts of the builders. It was comparatively new. Under working-test, the wheels had failed to give as much power as was anticipated. The water available being of limited quantity, the builders of the plant had spent some time tuning the wheels up to their highest efficiency. After they had reached their best results, another maker attempted to improve the efficiency by substituting his buckets, but without success. On one wheel, however, the original buckets were removed and ellipsoidal buckets substituted in their place, all other parts of the plant, that is, the nozzles, generators and other apparatus, being left in their previous condition. With the same quantity of water delivered through the same nozzle, the ellipsoidal buckets carried an increased load of 10½ per cent. above the best results of the builders. This was indicated on the switchboard-ammeter, which gave the increased horse-power output of the generator, secured simply by substituting the ellipsoidal for the original buckets. The changing of these buckets and the testing were done by the employees of the San Joaquin Electric Company, the makers of the ellipsoidal buckets not being represented.

A number of other tests have been made, all of which have shown an increased efficiency of from 10 to 15 per cent., depending, of course, upon the efficiency of the original wheels.

The Lagrange Dam, California.

BY E. H. BARTON, ROBINSONS, CAL.

(California Meeting, September, 1899.)

THE necessity, on the Pacific Coast and throughout the semi-arid regions in particular, of the conservation of waters for agricultural, industrial and mining purposes has forced itself upon the minds of those directly or indirectly interested in these industries. To meet the requirements of the case, storage must be provided for the flood-waters so abundant during the rainy season in order to insure a constant and unfailing supply during the summer months. Such storage can only be obtained, in the greater number of instances, by the erection of reservoir-walls of great height. The feasibility of employing earth or timber in the construction of such high dams is questionable, especially when (as is often the case) they must be placed in torrential streams.

The experience of recent years with masonry dams, throughout this and foreign countries, has demonstrated that such dams, when intelligently and correctly designed and properly constructed, will meet the requirements of larger storage by means of increased height.

The failures of masonry dams have been few; only two of any consequence being on record, namely, that of the Puentes dam, in Spain, in 1802, and that of the Habra dam, in Algiers, in 1810.* On the other hand, the failures of wooden and earthern dams are innumerable. The following are some of the most important structures constructed in recent years. The list is taken from Mr. Wegmann's book, just cited:

The Furens, Zola, Ternay, Ban and Verdon dams, in France; the Nizar, Lozoya, Villar and the two Hizar dams,

* See *Design and Construction of Masonry Dams*, by Edward Wegmann, C. E. Wiley and Sons, New York, 5th ed., 1899.

in Spain; the Cagliari dam, on the island of Sardinia; the Gorzente dam, near Alexandria, Italy; the Gilleppe dam, in Belgium; the Vyrnwy dam, in England; the Geelong dam, in Australia; the Poona dam, in India; the Toolsee dam, near Bombay; the Tytam dam, in China. In America, the Bridgeport, Boyd's Corner and Sodom dams in the East, and the San Mateo, Bear Valley and Sweetwater dams in California, are notable structures of their kind.

In the present paper I have endeavored to give a detailed description of the Lagrange dam and its construction.

Description of the Dam.

In 1890 the Board of Directors of the Turlock and Modesto irrigation districts instructed its engineers to prepare plans and specifications for a weir-dam on the Tuolumne river, 1½ miles above Lagrange, in Stanislaus county, Cal. Plans for a masonry structure 97 feet in height were prepared, and submitted to Col. G. H. Mendell, U. S. Engineers, for approval. Col. Mendell suggested changes in the profiles submitted, which were incorporated in the final plan, prepared by the writer to meet the increased height required by the discovery, in clearing foundations, that the soundings had not reached solid and firm bed-rock. It was found that the river-channel had been filled to a depth of 32 feet with boulders from 1 to 5 cubic yards in size, the interstices being occupied with sand and gravel. Consequently, a new profile was designed to suit an increase of 32 feet in the height of the structure.

The site chosen offered great advantages with regard to solidity of the flanking abutments, soundness of rock-formation, and dip of strata.

In designing the profile particular care was exercised to meet the torrential phases of the flood-season, which are very severe, the river rising at the dam-site, during heavy rains, 20 feet within an hour.

The contract for construction was let to the Pacific Construction Co. (R. W. Gorrill, President), and preparatory work was commenced in May, 1891.

The plant for this work comprised:

1. One 60 H. P. engine and boiler, furnishing power to operate a No. 4 Gates rock-breaker, a revolving cylindrical washer

(3 feet in diameter and 16 feet long, inclined 6° from horizontal), and one cubical mixer (5 feet on a side).

2. Six 12 H. P. donkey winding-engines for derricks* and sand-tramway.

3. One 25 H. P. portable engine and boiler, to run a 10-inch centrifugal pump for pumping seep- and leakage-waters.

The head-dam, for turning the river into a flume, was constructed of timber, and the river was carried over the site in a flume 4 by 12 feet in size and 400 feet long, with a grade of 1 in 100, giving a velocity of 20 feet per second and a discharge of 840 sec.-feet. A natural reef formed the tail-dam below the dam-site.

The flume was constructed of sufficiently strong material; the bottom being of Oregon pine plank, 4 by 12 by 18 inches, sized and surfaced on one side, and the sides of Oregon pine, 3 by 12 by 18 inches, likewise sized and surfaced on one side. The supporting yokes were placed 4.5 feet from center to center; the under-pinning was 8 by 10 inches in size; and the stringers, four to each bent, were 6 by 12 inches, the under-pinning-bents being placed 9 feet from center to center. This permitted the material (except the large stones) to be removed, hoisted and dumped into the flume, and carried away without the expense of wheeling or tramming.

Three derricks, with 70-foot masts and 60-foot booms, were stepped on the site of the dam, two of the same dimensions being erected at the quarry.

The broken stone used for concrete was quarried above the rock-breaker floor, crushed, wheeled into the hopper, discharged into the washer and thence into a car; thence run over the mixer and dumped (see Fig. 1). Water was introduced into the washer through hose under 60-foot head, with spray-nozzle.

The first concrete and stone were laid July 5, 1891. By October the work had so far advanced (the lower spill-ways being completed) as to permit the removal of the flume and the return of the river to its channel; the spill-ways being of ample size to carry its flow.

* In June, 1892, the Lidgerwood elevated rope-tram system was substituted for derricks.

Work progressed uninterruptedly until February, 1892, when the spring freshets filled the spill-ways and overflowed

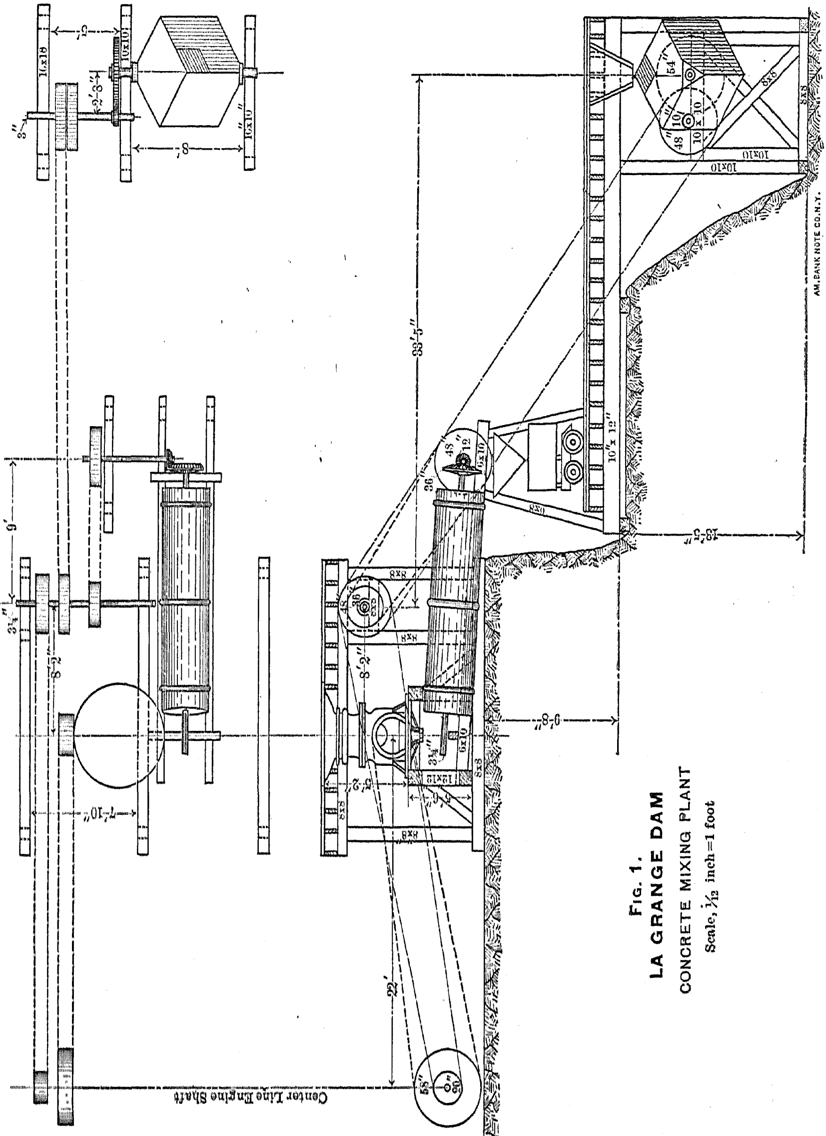


FIG. 1.
LA GRANGE DAM
CONCRETE MIXING PLANT
Scale, 1/12 inch=1 foot

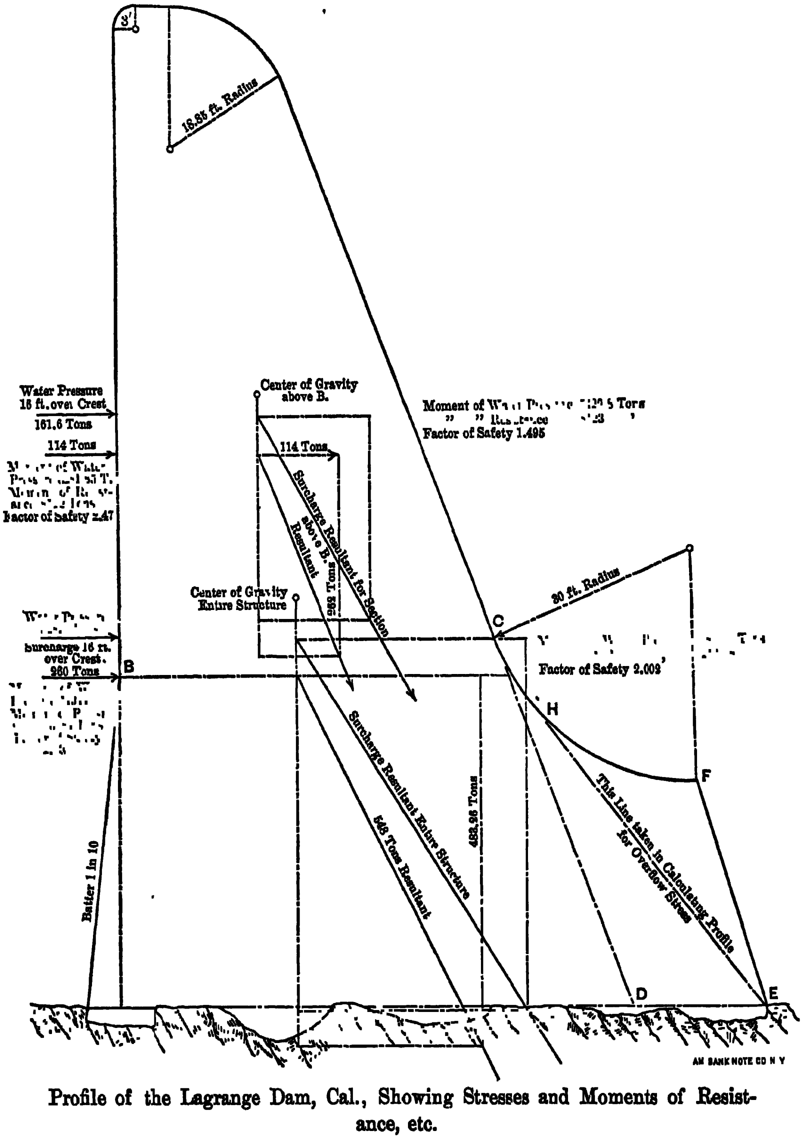
the top of the dam (then 56 feet in height) to a depth of 8 feet.

Work was resumed about June 1st, and continued with but

little interruption until completed; the pressure above the spill-ways increasing with the increased height of the dam.

These spill-ways readily passed the flood-waters, with the exception of the highest.

FIG. 2.



Profile of the Lagrange Dam, Cal., Showing Stresses and Moments of Resistance, etc.

The plan of the dam is curved, the radius of the up-stream face being 300.815 feet. Fig. 2 shows the profile and the stresses, overturning- and resistance-moments.

It will be seen that, when the overflow reaches 16 feet over the crest, the resultant of forces of the section above the line B does not fall within the middle third of the base of the section. The base of the section (or line B) is 4.75 feet below the point of the curve on the front face where the reactionary or reverse pressure of the overflow, passing from tangent to curve, is greatest, and will throw the line of pressure towards the back of the dam-wall, within the middle third.

In the parallelogram of forces for the entire profile under surcharge-stress, the line of profile is taken from the extreme toe to a point tangential to the curve, as indicated by line at E, Fig. 2.

The overflow being deflected slightly above the horizontal from the lower point of the curve, the reverse pressure diminishes from that point downward; hence the resistance of the structure alone enters into the calculations of stresses and overturning-movements under 16-foot surcharge; the resultant falling well within the middle third.

That portion of the profile on the front face, from the point C on the curve to D, E, F, has been excluded in calculating the weight of the gravity-section. It may seem to have been a waste of material to add the portion of profile C, D, E, F; but it must be admitted that this not only prevents any possible erosion at the toe of the dam, which would jeopard the stability of the structure, but also materially reinforces the toe to withstand crushing.

A slight batter was given to the back for 50 feet up. It was not deemed advisable to construct such a high masonry wall on entirely vertical lines, especially when it had to be built in the shortest possible time, so that the work was green at its completion, and not seasoned sufficiently to carry the superincumbent weight with absolute safety.

The actual amount of arch-action which takes place in a curved dam is, as yet, an uncertain quantity. That such action does take place and is an important element in the stability, is evidenced by the Bear Valley dam in California. In this case, assuming the weight of masonry at 166.7 pounds per cubic foot (specific gravity 2.66), we find that the line of pressure (reservoir full) lies almost entirely outside of the profile.*

* See Mr. Wegmann's book, already cited.

The Zola dam in France is another instance, in which the resultant, at the height of 62.32 feet above base, would be but 9.02 feet inside of the wall, the height of the dam being 119.76 feet.

Plan of Work.

The bed-rock having been thoroughly cleaned, and all shaly and unsound portions removed, sound portions roughened and channeled, the front and back faces (uncoursed rubble) were carried up with the interior of the dam (cyclopean rubble).

The concrete being tamped until the mortar flushed to the surface, the bed was prepared for stones weighing from 1 to 5 tons, the spaces between these being filled with concrete, smaller stones and spalls until sufficient space for the still larger stones was obtained.

Two spill-ways, 20 feet above bed-rock and 4 by 5 feet in size, and one, 40 feet above bed-rock, of the same size, carried the water during ordinary floods.

When the structure was completed, these were closed by wooden doors, hinged on top, and dropped into place, the water-pressure forcing them well to the seat. A 4-inch gas-pipe was then laid along the bottom of the spill-way from the front- to the back-face, a valve being placed at the lower end. These pipes conducted the seep or leakage through doors to the front of the dam. The spill-ways were then filled with concrete.

Two sand-sluices, 2 by 12 feet in size, and 20 feet below the crest of the dam, were provided with suitable gates.

To insure as nearly perfect work as possible, strict attention was paid to the details. Every stone entering into the structure was examined as to soundness, thoroughly washed with a jet under a pressure of 100 pounds per square inch, and scrubbed to insure the adhesion of the cement-mortar. Any mortar or concrete that had commenced to set before being used was rejected and removed from the work. All concrete was tamped until the mortar flushed to the surface, to insure the filling of voids and interstices. The concrete and masonry was allowed 21 days to become dry, after being put in place. All cements were tested, and the different proportions for concrete and mortar were measured, to insure uniformity in the work.

Broken rock and sand were moistened before entering the mixer, and the cement was added dry: 11 revolutions of the mixer gave to each particle of broken rock a perfect coating of mortar.

At the points where the dam rests against the abutments, the latter were cut to the radial lines of the curve. All of the flood-waters having to pass over the crest of the dam, it was of the utmost importance to prevent concussion and vibration. In that respect the profile of the dam has met every expectation, the water having a gliding motion throughout, and never leaving the face of the dam or causing a tremor in the structure.

The dimensions of this dam are: Diameter at base, 91 feet; height, 129 feet; length of crest, 336 feet; total volume, 39,165 cubic yards. In its construction, 29,040 barrels of cement were used.

Reminiscences of the Early Anthracite-Iron Industry.

BY SAMUEL THOMAS, CATASAUQUA, PA.

(An Address at the California Meeting, September, 1899.)

THE specimen of anthracite coal which I hold in my hand, insignificant as it may appear to the casual observer, speaks volumes to me and to the initiated, as it suggests and represents the entire evolution of the use of anthracite coal in the manufacture of pig-iron, the growth and development of which it is my purpose to review here to-day.

During our recent visit to the Mountain Copper Co.'s works at Keswick, I picked up this piece of coal from a pile of anthracite lying in the yard, asked Mr. Edwards, the manager, a countryman of mine, where it came from, and, to my surprise and delight, discovered that it had been brought all the way from Wales, and had come out of the identical vein which my father opened near Yniscedwin, about eighty years ago. I had no idea, before this incident, of contributing to the already full and complete programme of the day; but, being requested by our distinguished President and Secretary to do so, I consented to relate here the story which this remarkable find naturally brought back to my mind.

David Thomas, my revered father, called by his Welsh countrymen "the pioneer of the anthracite iron-trade in America," was one of the principal actors in the history of manufacturing pig-iron with anthracite coal. I shall give here my personal recollections of his early experiments, trials, and final successes, as frequently related by him to me, together with quotations from a biographical sketch by E. Roberts, found in the number for October, 1883, of the "Red Dragon," the national magazine of Wales. Mr. Roberts's narrative is authentic, by reason of his free access to the records of the Yniscedwin anthracite iron-works during his long connection with them. He says:

"Mr. David Thomas was the only son of David and Jane Thomas, of Tyllwyd (Gray House), in the parish of Cadoxtan, Glamorganshire, South Wales. Here he was born November 3rd, 1794. David Thomas, his father, was one of the numerous poor farmers of the country, but a man highly respected in his parish, where, although a dissenter, he held the honorable office of church-warden in the Established Church, and was overseer of the poor for sixteen years. Young David's early religious and moral training was of the strictest kind, both as regards example and precept; and he clung to these deeply inculcated principles all through life. Being an only son, his parents were anxious to give him the best advantages their means allowed, and the district afforded; and he attended school at Alltwen (White Grove), where he made such progress that, when nine years old, he was removed to a more advanced school at Neath, his father paying one guinea a quarter for tuition, which, at that remote period, was considered a large amount. The lad, studious by nature, delighted in books, and in acquiring knowledge and information, and was determined to get on. He soon outstripped all his school-fellows, and yet had succeeded in acquiring only the elements of an education, as compared with the opportunities offered the boys of to-day.

"It was by dint of undaunted perseverance, industry and personal effort that he attained the prominent position to which he ultimately rose. David was often called upon to assist in the operations of the farm; but agricultural pursuits were not to his taste, and his thirst for knowledge and improvement awakened in him an ambition which small farming-interests failed to satisfy. In 1812, when 17 years of age, he determined to branch out in a line of life which presented better prospects, and accordingly found employment at the Neath Abbey iron-works, erected on the navigable river Neath. They consisted of two cold-blast coke-furnaces, machine-shops and foundry, owned by a fine old Quaker gentleman named Price, who was one of the largest builders of mining-machinery and Cornish pumping-engines of that day. Here young David spent five years, acquiring his technical training in the machine-shops and foundry, while devoting his leisure hours to the study of the workings of the blast-furnaces. In 1817, when 23 years of age, after having spent several months in Cornwall erecting a pumping-engine, he went to the Yniscedwin iron-works, then owned by Richard Parsons, and here was made general superintendent of the furnaces and of the coal- and iron-mines, which position he occupied for twenty-two years, working the furnaces most successfully.

"Some three years later, these works came under the control of George Crane, after whom the Crane iron-works at Catasauqua, Pa., were named.

"It so happened that the Yniscedwin works actually stood on the only basin of anthracite coal in Great Britain, which contains several veins, and extends from the upper part of the Vale of Neath in Glamorganshire, on the east, to Saundersfoot in Pembrokeshire, on the west, the plant being on the southern edge of the coal-field in the Swansea valley; and yet, although these furnaces were underlaid and surrounded with this valuable material, coke was brought a distance of fourteen miles to supply them with fuel. Throughout this entire basin the argillaceous clay-iron-stone and 'black band' are stratified, and supplied the furnaces of that region with iron-ore.* Mr. Thomas was often heard to say that the Almighty had not wasted His creative powers in putting these materials together for no purpose; and on that faith he began his experiments.

"As early as 1820 Mr. Thomas began to experiment with anthracite coal in the blast-furnaces, using it with coke in the proportion of from 1 part in 20 to 1 part in 12. 'This did very well,' Mr. Thomas used to say; 'but whenever anything went wrong with the furnaces the fault was always laid on the coal; and the men became so prejudiced against it that I had to give it up. Still, every year I would try some experiments with it, both in cupola and blast-furnace.' . . . 'In 1825 I had a small furnace built, 28 feet high and 9 feet bosh, which was put in blast with coke and an increased amount of anthracite. Results were not satisfactory, and this furnace was abandoned. In 1830 the same furnace was made 45 feet high and 11 feet bosh; and, while the experiments were much more successful than previously, the consumption of coal was so great as to make results unprofitable, and the work was again abandoned.'"

Mr. Roberts continues:

"About this time experiments were also being made in Pennsylvania, but with no better success than in Wales. While this was being done on both sides of the Atlantic, another brain was at work, which furnished the key that unlocked the secret to success, by Mr. Neilson of Glasgow, the inventor of the hot-blast, who in 1828 obtained a patent for his valuable invention, the importance of which was not realized for a long time. The pamphlet on the hot-blast, issued by Neilson, was eagerly read by Mr. Thomas, who was at once convinced of the value of the discovery. One evening, while sitting with Mr. Crane in his library, talking the matter over, he took the bellows and began to blow the anthracite fire in the grate. 'You had better not, David,' said Mr. Crane; 'you will blow it out.' And Thomas replied, 'If we only had Neilson's hot-blast here, the anthracite would burn like pine.' Mr. Crane said, 'David, that is the idea precisely,' and this idea both recognized as one which would bear working out; and through Mr. Thomas's indomitable pluck and perseverance it succeeded. In fact, this was the origin of the successful application of the hot-blast in making iron with anthracite. In the meantime the Clyde iron-works, in Scotland, had put a furnace in operation, using the hot-blast with semi-bituminous coal in the furnace. Mr. Thomas urged upon Mr. Crane the immediate adoption of the new discovery, and he was sent to Scotland to see how the process worked. After the most careful examination, Mr. Thomas determined that the hot-blast was just what was wanted for an anthracite-furnace. He returned to Yniscedwin with a license from Mr. Neilson, and an expert mechanic who understood the construction of

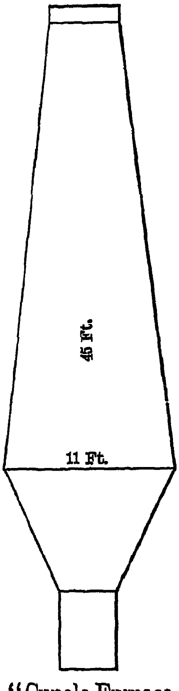
* These ores were long since exhausted; and every furnace in that region has been in ruins these twenty-five years and more.

heating-ovens, and at once proceeded to construct hot-blast ovens, and erected them at the furnace which was known as the 'Cupola furnace,' 11 feet bosh by 45 feet high. The furnace was blown in, February 5, 1837; the success was complete; and anthracite-iron continued to be profitably made from said furnace without intermission.

"Anthracite-iron was a new-born commodity in the commerce of the world, and David Thomas was its godfather. The news of his success spread over the United Kingdom; the London *Mining Journal* gave it great prominence; and an account of the discovery appeared in the press of the United States."

Fig. 1, copied from Truran's work on "Iron," shows the lines of the "cupola furnace" mentioned in the historical summary quoted above.

FIG. 1.



"Cupola Furnace," Built at Yniscedwin Works, South Wales, in 1836, and Successfully Blown-in, in February, 1837.

In May, 1837, Solomon W. Roberts of Philadelphia came to Yniscedwin, saw the furnace in operation, and at once reported to his uncle, Josiah White, of the Lehigh Coal and Navigation Company, the successful application of the hot-blast there.* At this time, 1837–38, the Lehigh Coal and Navigation Company, and other companies whose splendid mines cluster in the neighborhood of Mauch Chunk, Pa., were experimenting in the use of anthracite in the blast-furnace, but with such small success that it was determined to send Mr. Erskine Hazard, one of the leading spirits of the company, and afterwards *the* leading spirit of the Lehigh Crane Iron Company, over to Wales, to investigate the practice at Yniscedwin and engage a competent person to come to this country to superintend the erection of furnaces on the Lehigh. Mr. Hazard arrived in November, 1838, and found the furnace in full and successful operation.

Prior to this date, my father had removed his family to Devynock for the better education of his children; and there, in addition to his other duties,

* Mr. Roberts was then located at the Dowlais iron-works, Wales, inspecting rails for his company, which was constructing a railroad between White Haven and Wilkesbarre. These rails were double-headed. About thirty-five years later the writer, then President of the Catasauqua Manufacturing Company, bought a quantity of these identical rails, which were rolled into spike-rods.

he constructed a tramway to the mines and furnaces, the road-bed of which is occupied to-day by the Swansea, Neath and Brecon railroad. Mr. Crane brought Mr. Hazard to our home, near Castle Dhu (Black Castle), a feudal ruin of the twelfth century. He was accompanied by his oldest son, Alexander Hazard, at present a resident of Catasauqua, Pa. Here took place the first interview with my father with relation to his going to America, Mr. Crane having strongly recommended him to Mr. Hazard as the only man who would answer the purpose. My father was very loath to leave his native land, chiefly on account of his aged mother; but at the persuasion of his ambitious and energetic wife, who felt that the new world held larger opportunities for her three sons, he entered into the following agreement, which was executed the last day of the year 1838. All the details of this transaction I remember distinctly, having been present on the occasion:

Memorandum of Agreement Made the Thirty-first Day of December, 1838, *between Erskine Hazard for the Lehigh Crane Iron Company, of the One Part, and David Thomas, of Castle Dhu, of the Other Part.*

1. The said Thomas agrees to remove with his family to the works to be established by the said company on or near the River Lehigh, and there to undertake the erection of a blast-furnace for the smelting of iron with anthracite coal, and the working of the said furnace as furnace-manager; also to give his assistance in finding mines of iron-ore, fire-clay, and other materials suitable for carrying on iron-works, and generally to give his best knowledge and services to the said company, in the prosecution of the iron-business, in such manner as will best promote their interests, for the term of five years from the time of his arrival in America, provided the experiment of smelting iron with anthracite coal should be successful there.

2. The said Hazard, for the said company, agrees to pay the expenses of the said Thomas and his family from his present residence to the works above mentioned on the Lehigh, and there to furnish him with a house, and coal for fuel—also to pay him a salary at the rate of two hundred pounds sterling a year from the time of his stipend ceasing in his present employment until the first furnace on the Lehigh is got into blast with anthracite coal and making good iron, and, after that, at the rate of two hundred and fifty pounds sterling a year until a second furnace is put into operation successfully, when fifty pounds sterling shall be added to his annual salary, and so fifty pounds sterling per annum additional for each additional furnace which may be put into operation under his management.

3. It is mutually agreed between the parties that should the said Thomas fail of putting a furnace into successful operation with anthracite coal, that in that case the present agreement shall be void, and the said company shall then pay the said Thomas a sum equivalent to the expense of removing himself and family from the Lehigh to their present residence.

4. In settling the salary, four shillings and sixpence sterling are to be estimated as equal to one dollar.

In witness whereof the said parties have interchangeably set their hands and seals the date above given.

ERSKINE HAZARD, (SEAL)
for Lehigh Crane Iron Comp'y.
DAVID THOMAS. (SEAL)

Witness—
ALEXANDER F. HAZARD.

It is further mutually agreed between the Lehigh Crane Iron Company and David Thomas, the parties to the above-written agreement, that the amt. of the D. Thomas salary per annum shall be ascertained by taking the United States Mint price or value of the English sovereign as the value of the pound sterling, instead of estimating it by the value of the dollar as mentioned in the 4th article, and that the other remaining articles in the above-written memorandum of agreement executed by Erskine Hazard for the Lehigh Crane Iron Co. and David Thomas be hereby ratified and confirmed as they now stand written.

This supplementary agreement was also duly executed.

The organization of the Lehigh Iron Co., prior to Mr. Hazard's going abroad, had been only an informal one. On Jan. 10, 1839, it was perfected, and the first meeting of the directors was held. The Board consisted of Robert Earp, Josiah White, Erskine Hazard, Thomas Earp, George Earp, John McAllister, Jr., and Nathan Trotter. They organized by electing Robert Earp President and Treasurer, and John McAllister, Jr., Secretary. In April they entered into articles of association, which are appended, as affording some idea of the foundation on which this staunch old company has arisen and flourished.

Articles of Association of the Lehigh Crane Iron Co., Made and Entered into Under and Pursuant to an Act to Encourage the Manufacture of Iron with Coke, or Mineral Coal, and for Other Purposes, Passed June 16, 1836.

WITNESS that the subscribers, citizens of Pennsylvania, whose names are hereto affixed, have associated themselves, under and pursuant to the Act aforesaid, for the purpose of making and manufacturing iron from the raw material with coke or mineral coal, and do certify and declare the articles and conditions of their association to be as follows:

Article 1. The name, style, or title of the company shall be Lehigh Crane Iron Co.

Art. 2. The lands to be purchased by the company shall be in Northampton, or Lehigh county, or both.

Art. 3. The capital stock of the company shall consist of one hundred thousand dollars, divided into two thousand shares of fifty dollars each, the whole of which has been subscribed for by the subscribers hereto, in the numbers of shares set opposite to their respective names.

Art. 4. The sum of twenty-five thousand dollars, being the one-fourth of the whole capital stock subscribed for, has been actually paid in.

Art. 5. The remaining installments on the stock, already subscribed for, shall be called in such sums, and at such times, and with such forfeiture for non-payment thereof, as the Board of Directors may prescribe.

Art. 6. The Board of Directors shall consist of such a number of persons as the stockholders may from time to time prescribe.

Art. 7. This company shall in all things be subject to and governed by the provisions of the Act of Assembly under which it is created, and shall have the same and no other or greater powers, privileges, and franchises than are conferred upon it by virtue of the said Act.

PHILADELPHIA, April 23, 1839.

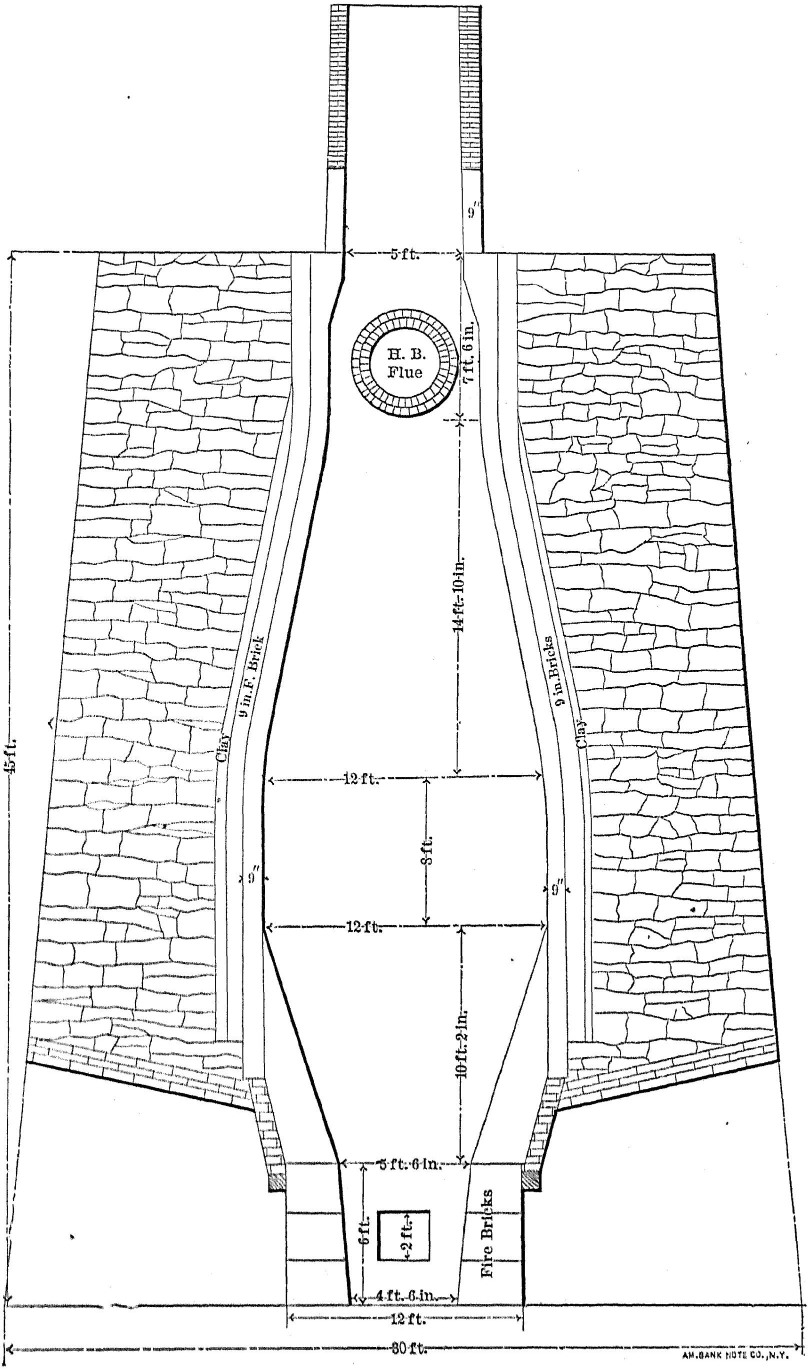
Signed	JOSIAH WHITE,	JOHN MCALLISTER, JR.,
	ERSKINE HAZARD,	ROBERT EARP,
	THOMAS EARP,	THEODORE MITCHELL,
	GEORGE EARP,	NATHAN TROTTER.

The first week of May, 1839, found our little family group at Swansea, on board of one of the coast-steamers on our way to Liverpool, as there were no railroads across the country at that time. The steamer "Great Western" had made but two or three voyages across the Atlantic; so, after much discussion among the parties interested, it was decided that, as steam was still considered a dangerous venture, we should take a sailing-vessel; and our passage was engaged on the clipper-ship "Roscius," commanded by Captain Collins, cousin of E. K. Collins, of the celebrated line of steamers of that name. The "Roscius" and the "Great Western" left port on the same day; the steamer arriving in New York but four days in advance of the clipper, which had an unprecedented voyage of twenty-three days. Our first month on American soil was spent in New Brighton, Staten Island, where my father lay very ill of a fever, and was faithfully attended by Dr. Harcourt, the genial quarantine-physician. On his recovery, he took me with him to Philadelphia, where he had been called to attend a meeting of the Crane Co.'s Board, relative to his entering upon his duties. We returned to New Brighton July 4, and two days later turned our faces toward the Lehigh Valley, our future home, taking the New Jersey railroad via Jersey City and New Brunswick,—at that time the terminus of the road, which, it may be of interest to note, was laid with strap-rails.

From New Brunswick the journey was continued by stage, the first night being spent at Easton, and Allentown being reached July 9. Here we resided four months while our home was being built near the new works. On July 11 my father

and I started on foot for the site of the future works, near what was then known as Biery's bridge, where we spent several hours, making measurements from which to work out plans for the construction of the plant—I, then a boy of thirteen, carrying one end of the tape-line. About August 1, surveys and plans being completed, work was commenced on excavations for the foundations of the wheel-pit, and on a branch canal, 25 feet wide, which was to be the feeder or race-way to the water-wheels, and also the route for boats to bring material to the works. The excavation was under the charge of Robert McIntyre and William Paul. A little later, the hot-blasts and furnace-foundations were commenced; the furnace being some 30 feet square at the base, 12 feet bosh, and 45 feet high. Its lines are shown in Fig. 2. All the masonry was laid by Isaac McHose, Sr., of Rittersville, whose son Samuel was subsequently the builder of nearly all the furnaces in the Lehigh Valley. The hot-blasts, with the usual bed-pipes, consisted of four ovens of 12 arched pipes each, 5 inches interior diameter, 1½ inches thick in the legs and 2 inches thick in the arch. They were built on the ground and fired with coal, having deep closed ash-pits, into which blast was introduced for active combustion, in lieu of a draft-stack. The arch-pipes were not connected with the nozzles on the bed-pipes by a socket and [illegible] as in later years. The joints were made with liquid cast-iron, the point of junction on the arch-pipes and nozzles on bed-pipes being carefully luted to prevent the iron from running into the bed-pipes. A pattern in three parts one inch thick, corresponding to a socket, was placed against the pipe and nozzle with sand packed around it, and when drawn out left a space into which the iron was poured. On the side of two pieces of the pattern was a hub in which was placed a core of the depth of the socket, for the purpose of driving a steel pin, to split it in renewal of pipes. Melting the iron was done in a small movable cupola placed at the end of the ovens and blown by hand with a very large blacksmith bellows; and the melted iron was carried in small hand-ladles to pour the joints. After the joints were made, they were deluged with salt and sal-ammoniac water, which rusted them perfectly tight. This plan was followed for several years. There were diaphragms in the bed-pipes, diverting the blast through three pipes from side to side;

FIG. 2.

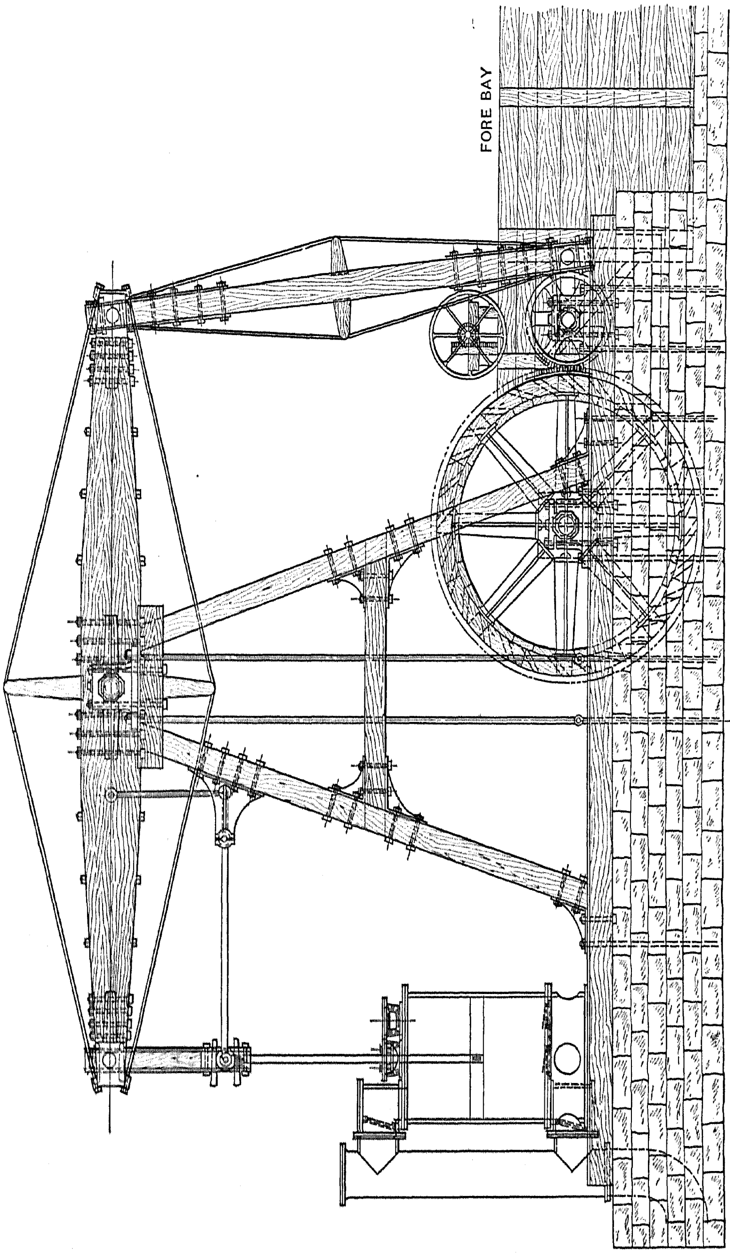


Furnace No. 1, Built at Catasauqua, Pa., 1839–40.

and, with good firing, a temperature of 600° was easily obtained; but, generally speaking, that was not maintained. The elevator for filling the furnace, called "a water-balance," consisted of two square boxes of sufficient size, one on each end of a chain, passing over a large wheel with a brake; a sufficient amount of water being admitted into the boxes on top to bring up a load on the other side, while the water escaped out of the boxes automatically at the bottom. No. 1 furnace was blown by a breast-wheel 12 feet in diameter and 24 feet long; the fall of 8 feet between the canal-levels at lock 36 furnishing the power. On each end of the wheel were segments on its circumference, of 10-inch face, geared into pinions on double cranks, these driving two blowing-cylinders having 5-ft. diameter and 6-ft. stroke, with parallel motion, and worked by beams on gallows-frames. The beams were constructed of two pieces each of white-oak timber, 14 by 16 in. in the center, and tapering towards the ends; the beams being also trussed with 1½-inch rods. The center-shaft of cast-iron, with extension-plate and flanged, was fitted between the timbers; and at the end heavy cast-iron spade-handles were also fitted between the timbers, for coupling the connecting-rods and links, all firmly bolted together, as shown in Figs. 3, 4 and 5. The blast from the cylinders was conducted underneath the canal through an 18-inch cast-iron pipe; this being the only receiver, the strokes of the cylinders could be counted at the furnace-tuyere as easily as in the wheel-house. (The wheelwrights who did the work were "Squire" George Frederick, with his sons, Thomas and Nathan, Edward Scherer, Thomas Barber, and John Leibert, father of Owen and Henry, now at the Bethlehem Steel Works.) About mid-summer of 1839, such portions of the outfit for this furnace as had been constructed on the other side of the Atlantic were shipped (some castings being made here later on), except the two blowing-cylinders, which the hatches of the ship were too small to admit. The vessel was also laden with rails for the Lehigh Coal and Navigation Co., and cleared for Philadelphia; but, having sprung a leak, she put into Norfolk, Va., in distress, after having jettisoned about 300 tons of the rails. On receipt of this news, Mr. Hazard and my father went to Norfolk and, to their consternation, found the cylinders were not there; the captain telling them, in

language more forcible than elegant, that if the castings in the hold had not been so heavy they would have gone over-

FIG. 3.



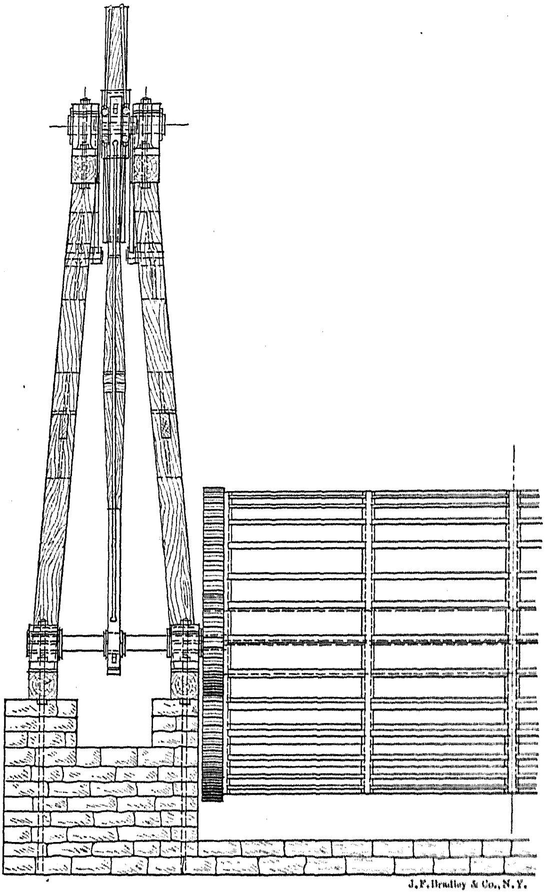
J. F. Bradley & Co., N.Y.

Water-Power Blowing-Engine, Crane Iron-Works, Catasauqua, Pa. Erected 1839–40. Vertical Longitudinal Section.
Scale: $\frac{1}{8}$ in. = 1 ft.

board also. After necessary repairs, the vessel proceeded to Philadelphia; and thence all the material for the furnace was

shipped by canal to the works. Steps were taken at once to procure cylinders. Application was made to Alger at Boston; the Allaire works, and the Morgan iron-works of New York; but they all declined to undertake the work, as they could not bore cylinders of that size, and would not enlarge their mills for the purpose.

FIG. 4.

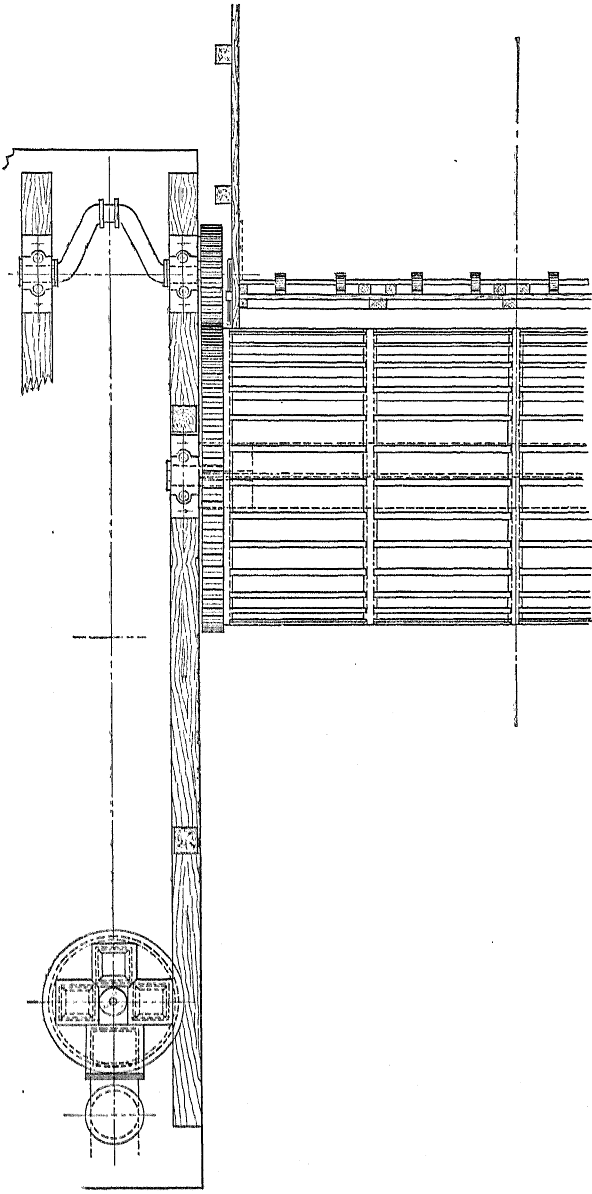


Vertical Cross-Section of Fig. 3. Scale: $\frac{1}{8}$ in. = 1 ft.

At this time there was not a boring-mill in the United States large enough to bore a cylinder of 60 inches diameter; but American progress in the construction of machinery was so rapid that in 1851 the I. P. Morris Co. of Philadelphia, Pa., made four cylinders for Ericsson's hot-air ship, of 168 inches diameter and 6 feet stroke.

Application was then made to Merrick & Towne of the Southwark foundry, Philadelphia, who agreed to undertake the work,

Fig. 5.



Plan of Blowing-Engine, Fig. 3. Scale: $\frac{1}{8}$ in. = 1 ft.

enlarging their boring-mill for the purpose, and succeeded in making two very fair cylinders, for which $12\frac{1}{2}$ cents per pound was paid. These cylinders were bored by Harry Smith,

who fitted them to the tops and bottoms sent from England, and subsequently erected them in place. The original cylinders, which had been so unceremoniously left on the docks at Cardiff, finally arrived at their destination in 1840. They were unloaded at lock 36, and one of them figured in the great flood of 1841, being rolled by the water a quarter of a mile down to Biery's bridge, where it lodged in a deep gully. Later, these cylinders were used in the construction of two blowing-engines, which were erected back of No. 1 furnace. They were in use there several years, and were then taken down, to make room for the present railroad back of the furnace. About 1866, the Lockridge Iron Co. was organized at Alburtis. I purchased these engines and erected them at the first furnace built there. The Lockridge Co. was later merged into the Thomas Iron Co., and these historical cylinders are in use by the latter Co. to-day.

After this long digression, I return to the history of the construction of the works. That all beginnings are hard, was never better illustrated than in this instance. Delays, difficulties and discouragements sprang up on every side, not least among which was the second serious illness of my father, keeping him housed during weeks in the autumn and greatly impeding the progress of the work, which he directed as best he could, using me as messenger to those in charge. The want of foundry-facilities was one of the greatest difficulties encountered; but finally the large cast-iron center-pieces, segments, gudgeons and pinions for the water-wheel were made at the Allentown Foundry, owned by George Brobst and Stephen Barber. It was at their foundry that the first steam-engine in Lehigh county was erected. It is preserved as a curiosity on the campus of Lafayette College at Easton, Pa.

After many vexatious delays, the furnace was completed and successfully blown in at 5 o'clock P. M. July 3, 1840, and the first cast of about 4 tons of iron was made on the memorable 4th of July of that year, the keepers in charge of the furnace being William Phillips and Evan Jones.

Looking back on those primitive times, I recall things which, done to-day, would seem ridiculous. For example, to prepare a furnace for blowing-in, a process called "scaffolding" the furnace was performed. The front or neck of the hearth was open, without the dam-plates. Across the knees of the back-

staves was thrown a bar of iron; and, over this and under the tymp, long heavy bars called *ringers* were driven several feet into the material in front, these bars holding it up, while below, all the clinkers and ashes that could be reached were shoveled and scraped out of the furnace; the dam-plate and *harp* were then put in place, and the bars were drawn out, allowing the front to fill up with fresh live coal. The plate called the *harp* was a long tapered plate with teeth like that of a saw, fastened against the dam-plate, and used to hold up the cinder-fall. The distance between the dam-plate and the tymp was about 24 inches. The blast-pressure being so light, it was not necessary to hold the plate down with props under the mantel, as in later years.

During the construction of the works, mines necessarily had to be opened for the supply of iron-ore. The first of these was Rice's mine, near Schoenersville, Hanover township. The first load of ore brought to the works was hauled from that mine by Henry Hoch. In the same neighborhood Goetz's and Daniel's mines were opened, and others in North and South Whitehall townships. The magnetic ore came from the Irondale, Byram and Dickerson mines in New Jersey, small lots being purchased from each place and shipped by the Morris canal. The proportion of ores generally used was one-fourth magnetic and three-fourths hematite. The furnace remained in blast until its fires were quenched by the rising waters of the great flood of January, 1841, a period of six months, during which 1080 tons of pig-iron were produced. The largest output for one week was 52 tons. Concerning the flood which I have mentioned, one of the Company's old books contains the following in my father's handwriting:

"On Thursday, January 7 (1841), at 9 o'clock in the evening, the river rose so that the back-water prevented the wheel from turning; at half after 10 covering the tow-path of the level above Lock 36. At 12 it was 2 feet over the banks and 1 foot over the bottom of the hearth of the furnaces. At 1.20 the water was at its height, and 34 inches in the furnace. It was at this height until 3.30 o'clock, when the river began to fall. The water-wheel was muddied all over, and the water lay 9 inches over its top. The dam and canal-bank were broken, so that when the water fell in the river it was too low to turn the wheel, though every effort was made to fill up the banks, with no good result, and we were obliged to *throw out* (shovel) the furnace on Monday, the 11th of January.

"David Thomas,
"Thomas S. Young (Book keeper)."

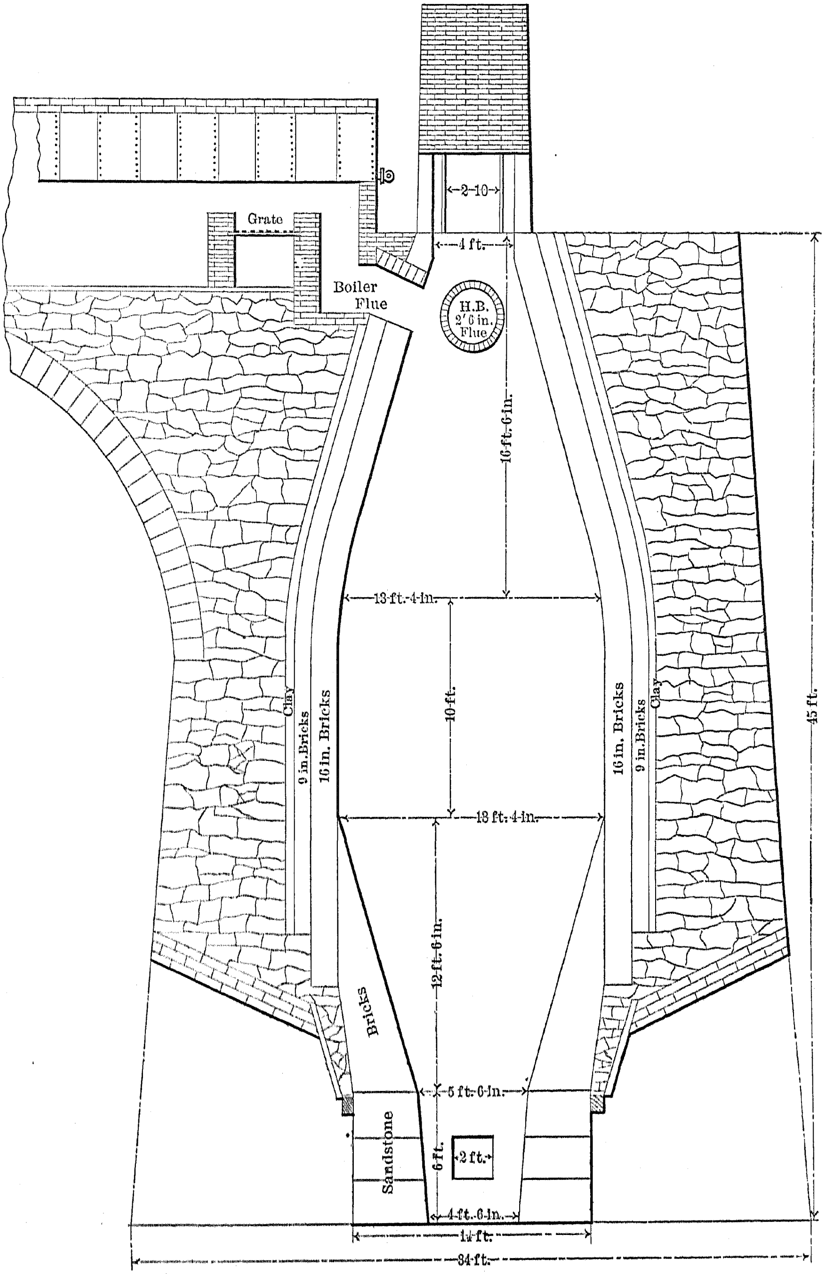
Furnace No. 1 was blown in again after the freshet, May 18, 1841, and then remained in blast until August 6, 1842, producing 3316 tons of pig-iron. My father had been very generally looked upon as visionary. The remark made by a leading charcoal-iron master, whom I well knew, "I will eat all the iron you make with anthracite," gave expression to the general sentiment of the trade at that time. It is needless to say that he did not keep his promise, although my father cordially invited him to a hearty dinner, cooked in the company's first furnace.

After the success of this furnace had been fully established, anthracite-furnaces began to multiply rapidly; Post built at Stanhope, N. J., Henry at Scranton, Firmstone at Glendon, Governor Porter at H[illegible]. Dr. Eckert at Reading; and by 1846 there were about 40 anthracite-furnaces in the country, distributed on the Lehigh, Hudson, Schuylkill and Susquehanna rivers.

In the latter part of 1841 the Crane company determined to build No. 2 furnace, and preparations were made accordingly. The furnace was built in the summer of 1842, and blown-in in November of the same year. It was 34 ft. at the base, 13 ft. 4 in. bosh, and 45 ft. high. The lines are shown in Fig. 6. The hot-blast was placed on top, additional space being provided by making the back of the furnace vertical for 25 feet, instead of giving it the usual batter. All the masonry, both brick and stone, was laid by David Walters, who had previously built a furnace at Farrandsville, Pa. (He was a most excellent mechanic, with peculiar ideas of his own: for instance, he prevailed on my father to allow him to put in the lining-brick of No. 2 furnace in spiral instead of horizontal lines; and inasmuch as one way was about as good as another, my father gave his consent.)

The blowing-apparatus for this furnace had 2 horizontal cylinders of 5-ft. diameter and 6-ft. stroke, driven by 2 Fourneyron turbines of 8-ft. outside diameter and 15-in. depth of bucket. On the upper end of the turbine-shafts was a 30-in. pinion geared into a heavy horizontal cog-wheel of 8-ft. diameter and 10-in. face, in which were inserted the crank-pins, and to these were coupled the necessary connecting-rods and cross-heads to drive the cylinders. Each machine was

Fig. 6.



Furnace No. 2, Built at Catasauqua, Pa., in 1842.

separate and was operated independently. All this machinery was made by Merrick & Towne, Southwark Foundry, Philadel-

phia. The blast was conducted to No. 2 furnace through the same pipe, under the canal, as to No. 1. The turbines proving great consumers of water, it became necessary to construct another canal as a feeder; the current in the old canal being so great that it was almost impossible to tow a heavily-loaded boat against it, so that the water on the water-wheels frequently had to be checked, to permit boats to pass through. A large force of men under Samuel Glace was put on the construction of the second canal, which was located on the south side of the old canal, and completed in about four months. The canal is therefore *double* at Catasauqua—a fact which has excited the curiosity of many. To protect it against floods, a cinder-bank was deposited on the outside, and upon this the Lehigh & Susquehanna Railroad is now laid, from the guard-lock at Hartman dam to Catasauqua station.

In 1843 an experiment was tried at this furnace—the first, I think, of the kind in this country—with the aim of utilizing the waste-gases for refining iron, taking out the gas at a depth of some 9 ft. below the top of the furnace. Previously the gases used for steam and hot-blasts had been taken out immediately under the dumping-ring, at the tunnel-head. The practical purpose of the experiment was the refining and puddling of iron for making an extra quality of bar-iron and wire. I quote from the furnace charging-book the following, in my father's handwriting, under date of October 23, 1843:

"On Monday night at 12 o'clock the blast was stopped on the furnace to build up gas-flues; there was 11½ inches of the backing of the furnace taken out, which was all calcined into lime." (The masonry of the furnace was limestone.) "The blast was put on again Saturday morning, October 28th, at 1 o'clock in the morning."

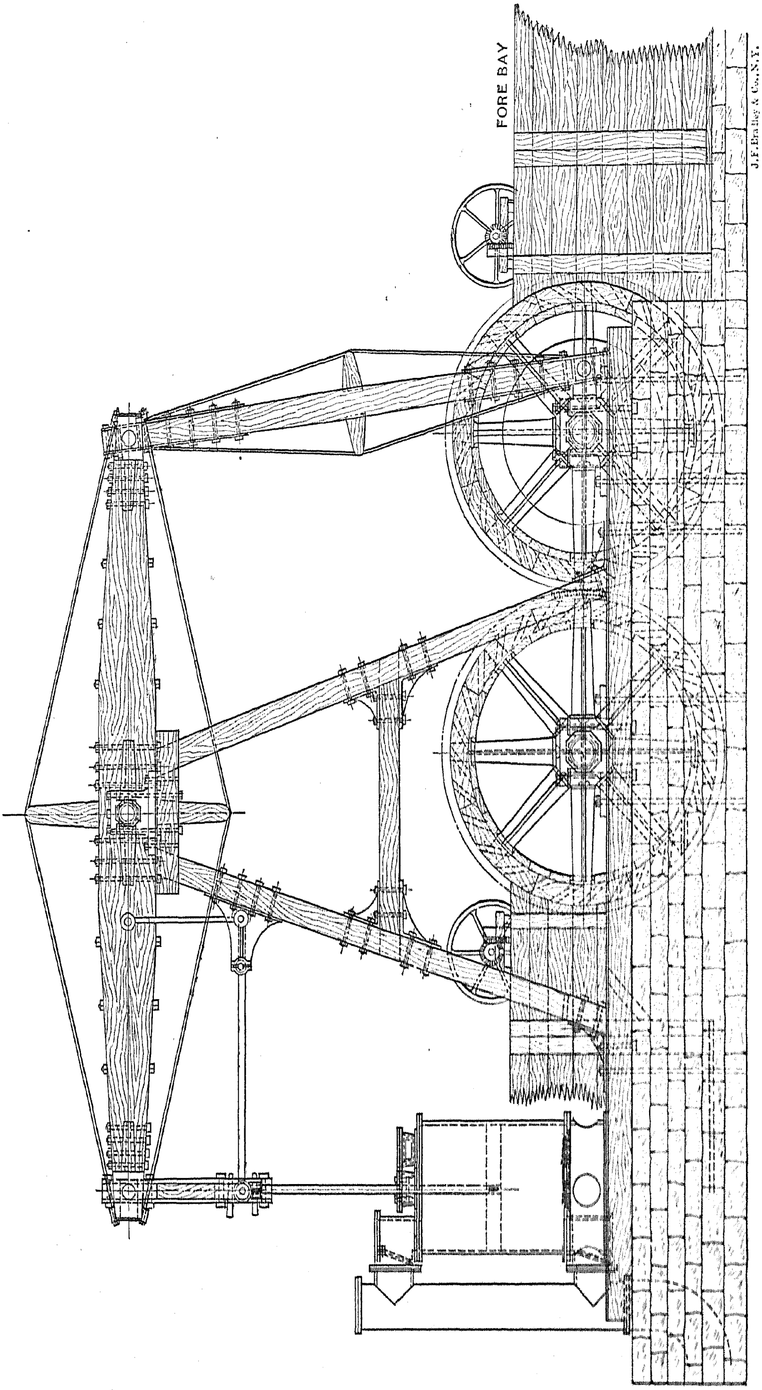
The construction of this refinery was very similar to that of a puddling-furnace. The gas was brought down through a conduit built of brick against the side of the furnace and conducted into one end of the refinery, passing over a bridge-wall into the body of the refining-furnace, which was built in a circular form, and on one side of which were inserted two tuyeres at an angle, to deliver the blast into the molten iron. Immediately back of the bridge-wall there were some 10 or 12 1-in. pipes, contracted at the tips, through which hot-blast was blown into the gas as it passed over the bridge-wall. So long

as the material which went into the furnace was dry, the gases came down at a high temperature, and the heat was intense and melted the iron very readily. After a rain, however, the wet material going into the furnace so reduced the temperature of the gases in the flues that it was insufficient to melt the iron. When successful heats were made, the metal was tapped into iron-chills about 3 ft. wide and 8 or 10 ft. long, making a plate 1 or 2 in. thick; and as soon as the iron was set it was deluged with water and broken up for shipment. Owing to the irregularity of the temperature of the gas, however, not more than 50 tons of metal were made in the six weeks of trial, and the experiment was abandoned as unprofitable. It was tried under the supervision of C. E. Detmold, an eminent engineer from Lippe-Detmold, Germany, a most genial man, of broad education and intellectual resources, whose name is associated with various important works and surveys in this country, among others the laying of the foundation of Fort Sumter, of historic memory. (Mr. Detmold was, at this time, the agent of Faber du Faur, inventor of the method of utilizing the waste gases of blast-furnaces.) He assigned to superintend this experiment young Edward S. Renwick, of the distinguished family of architects and mechanical engineers of that name, who, with his brother, subsequently built and owned a blast-furnace at South Wilkes-barre, Pa.

In 1844 the blowing-apparatus was reconstructed. As the blast to both furnaces was blown in common, the turbine-wheel proved so much more powerful that we could not get the necessary service from the breast-wheel. So the pinion and the double crank were abandoned, and the forebay to the first breast-wheel was shortened 8 ft., moving the wheel forward, which brought the center of the wheel directly under the point of the beam. We replaced the original gudgeon with one of 14-inch diameter, on which the crank-wheel was placed, connecting it with the original connecting-rod. To this was added another wheel, the same as the first, and they were geared together as shown in Figs. 7, 8, and 9. This gave us a blowing-apparatus fully equal to the turbine.

In 1845 it was determined to build No. 3 furnace; and the question at once came up, what power should be used for blowing. I well remember a consultation held on this subject at

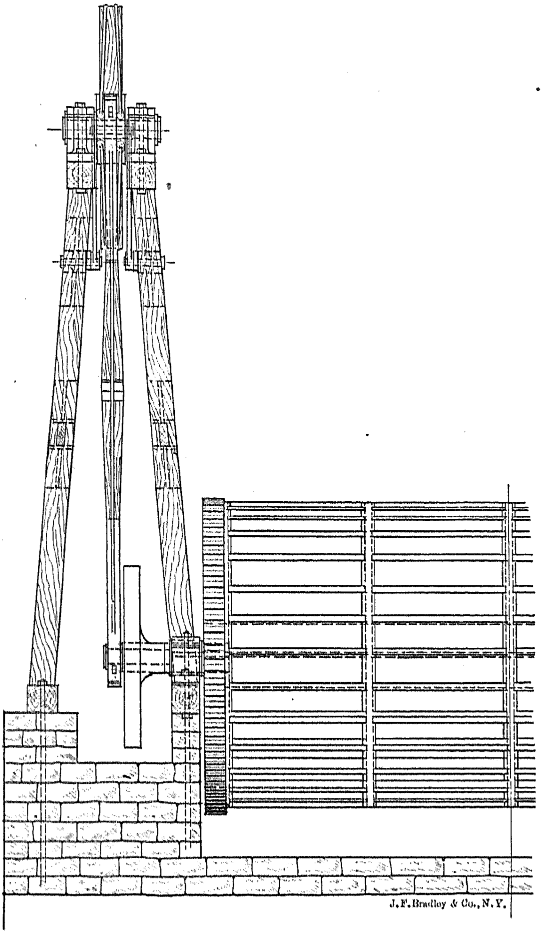
FIG. 7.



Blowing-Engine for Furnaces Nos. 1 and 2, as reconstructed in 1844. Scale: $\frac{1}{8}$ in. = 1 ft.

the Catasauqua office by Messrs. White, Hazard, E. A. Douglas, Engineer-in-Chief of the Lehigh Coal and Navigation Co., and my father. Mr. White was a great stickler for water-power, and almost insisted upon its being used. Mr. Hazard and my father were in favor of using steam-power, maintaining that

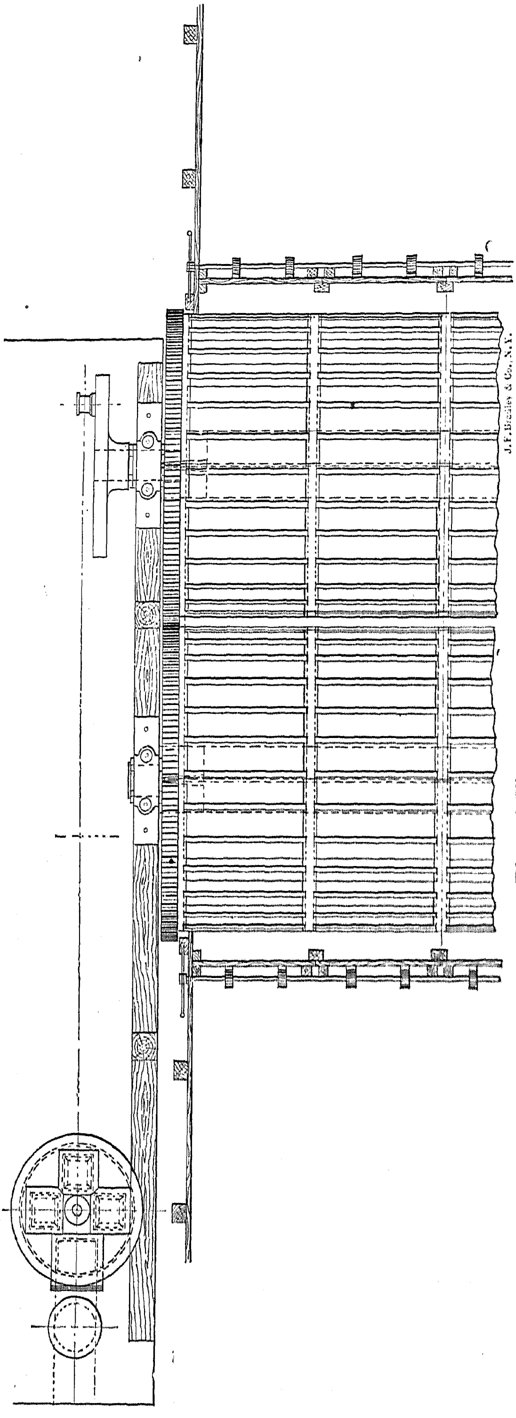
FIG. 8.



Vertical Cross-Section of Fig. 7. Scale: $\frac{1}{8}$ in. = 1 ft.

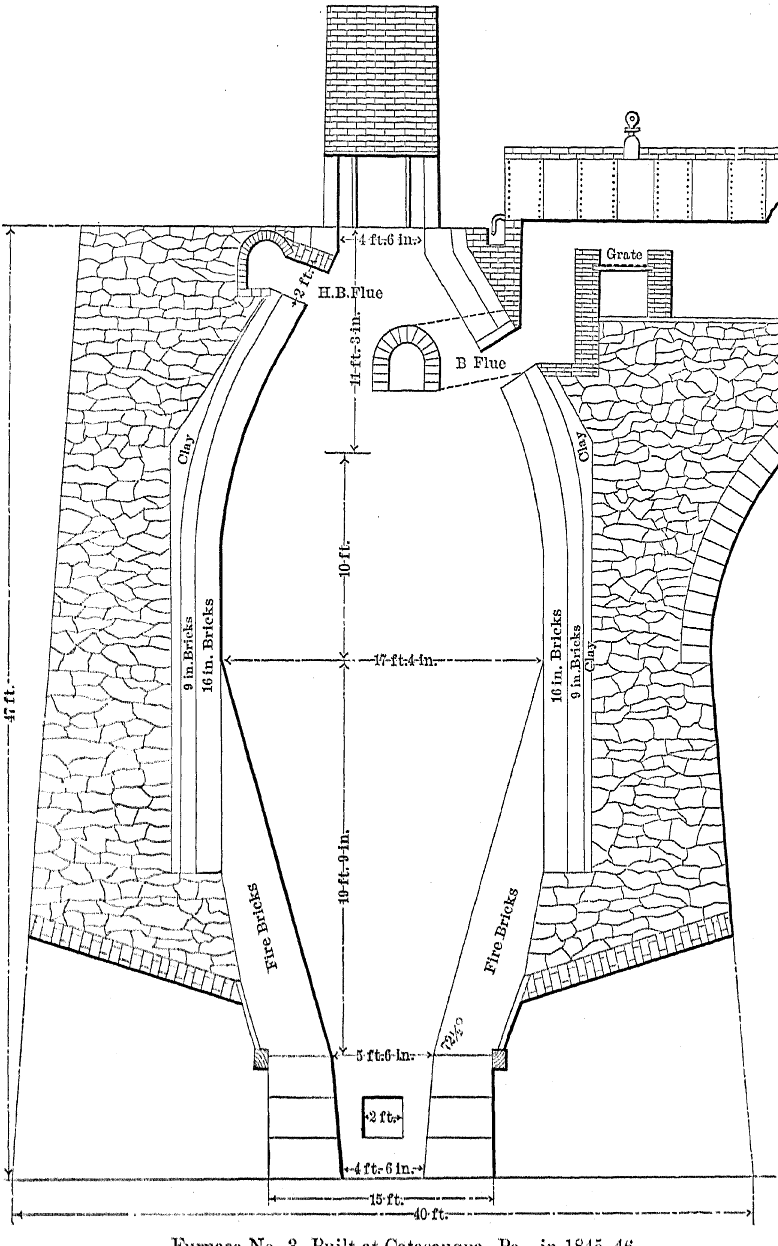
there was not water enough in the Lehigh during the dry season to blow an additional furnace. The discussion grew quite earnest, and Mr. White somewhat impatiently said to my father, "David, thee does not know what thee is talking about;" but as Hazard and Douglas coincided with my father, steam-power carried the day.

FIG. 9.



Plan of Fig. 7. Scale: $\frac{1}{8}$ in. = 1 ft.

Fig. 10.



Furnace No. 3, Built at Catasauqua, Pa., in 1845–46.

No. 3 furnace (see Fig. 10) was 40 ft. wide at the base, 17 ft. in bosh-diameter, and 47 ft. high, and was fitted with a water-balance, like the other furnaces. It was blown by a pair of

beam-engines connected with a single fly-wheel; the blowing-cylinder was $5\frac{1}{2}$ ft. in diameter and 6-ft. stroke; the steam-cylinders had 26-in. diameter and 6-ft. stroke, with slide-valve and a cut-off. A pressure of about 6 lbs. could be maintained, and with that the furnace did fairly well. These engines were built at the Allaire works, New York, and a Mr. Smith was the engineer in charge of construction.

In 1847 an experiment was tried at this furnace by passing a strong current of electricity through the molten iron, the battery for which consisted of 100 cells, very powerful and dangerous to handle. A heavy iron bar, with a heavy wire attached, was placed in the runner at the end of the casting-trough, and a second wire and bar were attached at the extreme lower end of the pig-bed, the current being maintained while the iron was flowing and for twenty minutes after the iron was set. This was carried on through some half a dozen casts; but the men became very shy of the wires, because Jimmy Hunter, the keeper, was knocked almost senseless by using an iron bar he held in his hand to remove one of the wires which was in his way. Consequently the experiment was tried in another way. A bar of iron was suspended from the top of the furnace down into the material to a depth of some 10 or 12 feet; to this one wire was attached, and the other to one of the tuyere-pipes. The current was kept up continuously for two weeks. The samples of iron produced in this experiment were puddled, with the idea that the electric current would be found to have dispelled the phosphorus; but the results showed no apparent difference from the iron otherwise made.

At this time, the steam-whistle was an unknown sound in the Lehigh valley. I had secretly had made by Lehman, Sr., a brass-founder of Bethlehem, a large whistle, which measured 8 in. in diameter, and about 15 in. in depth of bell; and when No. 3 was ready, and the whistle had been attached to the boilers and they were ready to be tested, and the pressure was up to 60 or 70 pounds, I "let her off." The noise startled the whole town and occasioned much laughter. Mrs. Noah Davis used to tell how she and the women on upper Church street rushed out of their houses to gather up their children, [illegible] as they heard the unusual sound, that it was the last trump.

During 1849–50 the Crane Co. built furnaces Nos. 4 and 5,

18 ft. in bosh-diameter and 45 ft. high. To drive these furnaces the most powerful blowing-engine in the country was erected, with blowing-cylinders 7 ft. and steam-cylinders 34 in. in diameter (high pressure) and 9 ft. stroke, which would exert with ease a blast-pressure of 8 to 10 lbs. per sq. in. With the volume of air that could be delivered, the furnaces were too low to do as well as was expected; so they were raised to 55 ft. high in 1852, after which the production ranged from 250 to 300 tons each per week. Figs. 2, 6 and 10, showing the lines of furnaces Nos 1, 2 and 3 of the Crane Co., were traced from sketches found among the papers of the late Joshua Hunt, who was connected with the works from 1843 to 1885. The flue shown in No 1 was not used until the hot-blast was erected on top in 1843. The section of arch shown in No. 2 was built between Nos. 1 and 2 and boilers placed on top when the two engines before mentioned were erected back of No. 1 in 1850, after which the breast-wheels were abandoned and only turbines were used, and these only up to 1858, when steam-power was resorted to exclusively. No. 3 as shown was built with one pier and two arches, one arch against No. 2, the other against No. 3, on which the boilers and hot-blast were placed.

As my friend of nearly half a century's standing, Mr. John Fritz, of Bethlehem, truly says in his reminiscences of the pioneer days of iron-making in this country, the active managers of the iron-works of to-day, possessed of all the facilities of telegraph, telephone and railroads, know little of the trials and tribulations of those arduous early times. It required three whole days to transact business between us and Philadelphia—two days to go and return by stage, and one to attend to business. When the roads were bad, it often took us twelve hours to reach the city.

Up to 1855 our only means of transportation for coal from Mauch Chunk, and magnetic ore from New Jersey, was the canal. The hematite ores and limestone were brought to the works entirely by wagon, the country literally swarming with teams. We paid in some instances as high as $2.00 per ton for transportation on some of these ores; and not until 1855, when the Lehigh Valley railroad was opened, and 1857, when the Catasauqua and Fogelsville line was partly finished, did we begin to have a taste of the labor-saving facilities so generally en-

joyed to-day. An immense amount of labor was required simply to pile up a sufficient amount of coal to run five furnaces during the four winter months. The unloading of the coal was all done by wheelbarrows; and the accumulation of our provision commenced in the spring, as soon as navigation was opened, and continued until the canal was closed, since we had to store not less than 40,000 tons in addition to what the furnaces were continually consuming. In 1847, with a view of expediting this work, we erected a large amount of trestling 25 ft. high, and a water-balance near No. 3 furnace, so that the coal could be unloaded into cars, elevated, and then dumped in this trestle-work. The first season's experience with this system was not encouraging. The rains and snows of winter caused the coal to freeze; and it would come down in great masses, often breaking the legs of the trestles and crushing the coal, making much waste. After the second season the labor-saving apparatus was abandoned and the wheelbarrow was again resorted to.

As already remarked, on leaving home I had not the least idea of presenting this paper before the Institute; but this providential opportunity being offered I gladly embrace it, desiring to correct certain misapprehensions and wrong impressions concerning the great discovery in question, and feeling it my duty to establish, even at this late day, the claims of my father to the *successful* application of the use of anthracite in the production of pig-iron. The facts given I have from my father's own lips. That he did not assert himself more emphatically at the time was due to his modesty and to lack of means and influence to obtain a patent, which was no small undertaking at that time in Great Britain. Mr. Crane has often received the credit of this useful discovery. With all due respect to his memory, I must state that he was in no sense of the word a mechanic or a technical man, but a shrewd business man, with a faculty for recognizing the merits and promoting the commercial utilization of the inventions of others—a faculty, by the way, which is as essential to industrial progress as the genius of the investigator and inventor.

Josiah White's son-in-law, Richard Richardson, in his history of the early development of the Lehigh Coal and Mine Co. (afterwards changed to the Lehigh Coal and Navigation Co.), refers to

the building of the first furnace by my father for the Lehigh Crane Iron Co. He gives the history of Mr. Hazard's trip to Wales to inquire into the results at Yniscedwin and says:

"Mr. Hazard ordered such machinery as was necessary to be made for the company, under the direction of George Crane the inventor, and engaged David Thomas, who was familiar with the process, to take charge of the erection of the works for the manufacture of iron, and to his faithful and intelligent management *much* of the success of the enterprise was due."

It is not reasonable to suppose that Mr. Hazard, an entire stranger to the business, should have taken the responsibility of procuring the necessary machinery and other appliances for the erection of this furnace. The real facts are, that the whole matter was placed in my father's hands, and that, during the four months he remained in Wales after the signing of the contract with Mr. Hazard, he made all arrangements for the entire outfit of the furnace. The blowing-machinery was constructed at the Soho Works, England, and the hot-blasts at Yniscedwin from the same patterns as used there, under the supervision of John Clee, the assistant superintendent, who succeeded my father in the management of the works, while the fire-brick came from the Stourbridge works, England.

Mr. Swank, the author of that invaluable work, *Iron in all Ages*, commenting upon Mr. Richardson's version, says: "We do not hesitate to say that to Mr. Thomas' management was due the *whole* of the success of the anthracite-furnaces built by the Lehigh Crane works." Mr. William Firmstone, another eminent authority, says: "With the erection of this furnace commenced the era of higher and larger furnaces and better blast-machinery, with the consequent improvement in the yield and quality of iron produced." It has never been claimed that no anthracite pig-iron had been made in this country previous to 1840, but only that the commercial success of this manufacture dated from my father's work at Yniscedwin in 1837 and at the Crane works, Catasauqua, Pa., in 1840. I have the highest authority for the statement that not so much as 500 tons of anthracite pig-iron were made in this country during the entire experimental period preceding 1840.

Having long felt that a clear statement of the above facts was a tribute that I owed to my venerated father, the first president of the American Institute of Mining Engineers, I

have to the best of my ability now discharged this duty. Thanking you for your kind attention and patience, which I fear I have greatly taxed—such being the inevitable result of the host of recollections which rush upon my memory as I attempt to relate the early experiences of a career of nearly sixty years in this special work—I close with the lines of the poet Saxe:

> "My growing talk of olden times,
> My growing thirst for early news,
> My growing apathy to rhymes,
> My growing love of easy shoes,
> My growing hate of crowds and noise,
> My growing fear of taking cold,
> All whisper in the plainest voice,
> I'm growing old."

DISCUSSIONS.

The Evolution of Mine-Surveying Instruments.

Discussion of the Paper of Dunbar D. Scott, presented at the Buffalo Meeting, October, 1898. (See *Trans.*, xxviii., 679.)

NOTE BY THE SECRETARY.—Since the issue of vol. xxviii. the following additional corrections of Mr. Scott's original paper have been received:

Page 681, line 2 from bottom. "Munster" should be "Münster."

Page 682, line 5. "Beyern" should be "Beyer."

Page 682, line 17. "2364" should be "2634."

Page 683, lines 3 and 4 from bottom. "Diggs" should be "Digges" and "Leonhard" should be "Leonard."

Page 684, line 1. "*Theodolitus*" should be "*theodelitus*."

Page 684, line 2 from bottom. "The same year" should be "1579," and "Stratiaticus" should be "Stratioticos."

Page 685, line 15. "1590" should be "1608." The telescope given then to Prince Maurice was made by Lippershey, not Jansen.

Page 685, line 19. "1608" should be "1609."

Page 687, line 1. The reference here made is to *Höhere Markscheidekunst*, by Prof. Albert von Miller-Hauenfels, Wien, 1868, pp. 286–291.

Page 689, line 8 from bottom. "Strum" should be "Sturm." See his *Vier kurze Abhandlungen*, of which the fourth treats of the *Markscheidekunst als ein Anhang dem kurzen Begriff der gesammten Mathesis beizufügen*. Frankfurt a. d. O., 1710.

Page 689, line 4 from bottom. After "J. G. Studer," add: See *Ueber Eisenscheiben. Freiberger gemeinnützige Nachrichten*, No. 50, 1802. *Moll's Annalen*, II., p. 387.

Page 690, line 2 from bottom. "1537" should be "1590."

Page 690, line 2 from bottom. After "Leonhard Zubler," add: See his *Fabrica et Usus Instrumenti Chorographici*, Basel, 1625.

Page 691, line 12 from bottom. After "Dr. Lamont" insert (1840).

Page 694, line 11. "Helvetius" should be "Hevelius."

Page 694, line 6 from bottom. "Guiliani" should be "Giuliani."

Page 697, lines 16 and 17. "Dolland" should be "Dollond."

Page 697, line 4 from bottom. "1669" should be "1667."

Page 698, line 15 from bottom. "Bourne" should be "Bourns."

Page 699, at bottom. "Bohm" should be "Bœhm."

Page 721, line 4. "Gascoign" should be "Gascoigne."

Page 723, line 11. "British" should be "Argentine Mining and Metallurgical."

Page 739, line 10 from bottom. "Up" should be "upon."

Page 739, line 5 from bottom. "Steep horizontal angles" should be "horizontal angles measured with the telescope steeply inclined."

Page 740, line 10 from bottom. "Kelner" should be "Kellner."

All the following contributions to this discussion were received by mail:

BENNETT H. BROUGH:* Having devoted many years to a study of the history of mine-surveying, some of the results of which I published partly in a course of lectures† delivered before the Society of Arts in 1892, and partly in a separate work,‡ I consider that the information Mr. Scott has got together to illustrate the gradual evolution of American mine-surveying instruments during the past sixty-seven years forms a valuable contribution to knowledge. There are, however, several statements in the paper that are open to criticism. For example, the author is inaccurate in stating that the use of the compass in mine-surveys is first described by Agricola. As a matter of fact, it is described in the oldest treatise on mining, a work written in German and published anonymously in 1505

* Formerly Instructor in Mine Surveying, Royal School of Mines; Sec'y Iron and Steel Institute, 28 Victoria Street, London, England. This communication was received January 23, 1899.

† *Cantor Lectures on Mine Surveying*, by B. H. Brough, London, 1892.

‡ *A Treatise on Mine Surveying*, by B. H. Brough, London and Philadelphia; 1st edition, 1888; 7th edition, 1899.

under the title of *Ein wolgeordent uñ nutzlich büchlin wie man Bergwerck suchen und finden soll.* The wood-cut of the miner's compass there published shows the dial divided into twice twelve hours. In the library of the Freiberg Mining Academy there are copies of four editions of this rare and interesting book. Of the edition of 1505 only two or three copies are known.

A compass similar to that found at Neudorf, described in the paper, is exhibited in Florence. It belonged to Galileo.

A study of the history of surveying-instruments shows that in many cases inventions have been anticipated in a curious manner. Thus, the ingenious Rapid Traverser, invented by Captain Henderson in 1892, is, I find, very similar to an instrument invented by Brigadier-General James Douglas, and described by him in 1727, in a work entitled *The Surveyor's Utmost Desire Fulfilled, or the Art of Planometry, Longimetry and Altimetry, brought to its greatest Perfection by the Help of the Ungraduated Instrument, called the Infallible* (London: Printed for John Osborne and Thomas Longman at the Ship in Paternoster-row, MDCCXXVII.). The instrument is thus described:

"It only consists of two Pieces, viz., A and B, whereof A is a square Copper Plate, with two moving visual Rulers turning round upon the central Screw Nail D, passing through the Middle of the Plate A. It is furnished at each Corner with a thin Piece of Brass, which may be taken off and on at pleasure, each being pierced to receive headless Pins, which are soldred fast to the Plate; the four Screws are to make their Plates hold fast the Paper when properly folded at the Corners of the Instrument. To fit the Instrument for Use, first cover the Plate A with a double Sheet of clean Paper. Then B, your Ball and Socket, is to be joined by putting the Screw Nail thereof through the central Hole of the Plate A, gently piercing the Paper; which done, apply the two visual Rulers, and screw them fast with the middle Screw Nail so that the said Rulers move easily about the centre: and thus is your *Infallible* prepared for Use."

To those unacquainted with the delicate magnetic instruments used in Sweden for discovering iron-ores, the author's description of Thalen's magnetometer and Tiberg's inclination-balance as being almost identical will be misleading. These instruments, which should hardly be classed with ordinary mine-surveying instruments, were described in a paper on exploring for iron-ore with the magnetic needle, which I communicated to the Iron and Steel Institute in 1887, and were admirably illustrated in the important monograph read at the Stockholm meeting of that Society in 1898 by Professor G. Nordenström. For some years past a combination of the two

instruments has been found most suitable for magnetic explorations.

Surely Mr. Scott is mistaken in ascribing the introduction of the instrument shown in Fig. 14 to W. and S. Jones in 1796. I have in my possession a graphometer of precisely similar design, made at Brunswick in 1630; and graphometers of even earlier date are exhibited in the collection of astrolabes in the South Kensington Museum. The instrument appears to have been invented by Jan Pieterszoon Dou, of Leyden, in 1612, and described by him in 1620. These graphometers, being made prior to the invention of the vernier in 1631,* are of interest in being furnished with the *nonius*, or variously divided auxiliary quadrants, invented by Pedro Nuñez in 1542.

Referring to Mr. Scott's statement that a diaphragm and cross-hairs in the focus of surveying-instruments were first used in 1669, I may point out that Professor E. Hammer has shown that this was first done about the year 1640, in England, by William Gascoigne, who fell, in 1644, at the age of twenty-four, in the battle of Marston Moor. He used hair and thread for this purpose thirty years before Picard and Malvasia. In the middle of the last century glass and mica plates, with engraved lines, were first used in place of cross-hairs. They were described by Brander in 1772, and were used by Breithaupt in 1780. Spiders' webs were not used until 1775.

Credit for the first application of the tacheometric principle in surveying is given by the author to William Green, who was awarded a premium for its invention by the Society of Arts in 1778. This view I adopted in a paper on tacheometry, communicated to the Institution of Civil Engineers in 1888. It has, however, recently been shown by Mr. J. L. Van Ornum, in a scholarly memoir published by the University of Wisconsin, that, although in 1778 the Danish Academy of Sciences awarded a prize to G. F. Brander for a similar device, which he had applied to his plane-table six years before, its real discoverer was James Watt, who used it in 1771 for measuring distances in the surveys for the Tarbert and Crinan canals. In James Patrick Muirhead's life of James Watt is found a state-

* The vernier was invented by Capt. Pierre Vernier, a native of Burgundy, serving the King of Spain in the Netherlands. The Germans seem to have used the Teutonic form "Werner." See Bauernfeind's *Elemente der Vermessungskunde*, 7th ed., Munich, 1889, p. 124.—R. W. R.

ment by Watt himself that he constructed the instrument in 1770, and that in 1772 he showed it to Smeaton.

It is interesting to compare the perfect method of measuring lengths by means of the American steel tapes, referred to by the author, with that formerly employed. In an old German work on surveying by Jacob Koebel, published at Frankfort in 1570, the unit of length is described somewhat as follows: "A rood should, by the right and lawful way, and in accordance with scientific usage, be made thus: Sixteen men, short and tall, one after the other, as they come out of church, should place each a shoe in one line; and if you take a length of exactly 16 of these shoes, that length shall be a true rood." This description is accompanied by a quaint illustration showing the process being put in operation.*

MR. SCOTT: Mr. Newton had sent me an electrotype of Henderson's Rapid Traverser to accompany the text in my article which relates to it, but it was confiscated by our Government officials because the importation of small articles of merchandise through the mails has been unjustly prohibited by the Universal Postal Union Convention.

I cannot let Mr. Brough's description of the "Infallible" go by without citing one other of the progenitors of Capt. Henderson's Traverser, to which Adams has made casual reference in his *Essays*, the first edition of which was published in 1791. He says:

"Mr. Searle contrived a plain table, whose size (which renders it convenient, while it multiplies every error) is only five inches square, and consists of two parts, the table and the frame; the frame, as usual, to tighten the paper observed upon. In the center of the table is a screw, on which the index sight turns; this screw is tightened after taking an observation."

I did not wish to convey the impression that Jones' circumferentor (Fig. 14) was unquestionably the first of its kind in England, unless what Mr. Newton had ventured to say concerning it would tend to establish that fact. Possibly even Mr. Newton may be incorrect, for an old English work† has this interesting paragraph:

* *Geometrey von Künstlichem Feldmessen.* A copy of this rare book in the Astor Library, New York, is dated 1598. The edition of 1570, cited by Mr. Brough, is in the British Museum.—R. W. R.

† *Geodesia, or the Art of Surveying*, John Love, London, 1744, p. 59.

"This last instrument depends wholly upon the Needle for taking of angles, which often proves erroneous; the Needle yearly of itself varying from the true North, if there be no Iron Mines in the Earth, or other Accident to draw it aside, which in mountainous Lands are often found: It is therefore the best Way for the Surveyor, where he possibly can, to take his Angles without the help of the Needle, as is before shewed by the Semicircle. But in all Lands it cannot be done, but we must sometimes make use of the Needle, without exceeding great trouble, as in the thick woods of *Jamaica*, *Carolina*, &c. It is good therefore to have an Instrument with which an Angle in the Field may be taken either with or without the Needle, as is the Semicircle, than which I know no better Instrument for the Surveyor's Use yet made publick."

The semicircle Love describes had fixed and movable sights, though divided very coarsely; for in the preface of his work he says:

"I have taken Example from Mr. Howell to make the table of *Sines* and *Tangents* but to every fifth minute, that being nigh enough in all Sence and Reason for the Surveyor's Use; for there is no man, with the best instrument that was ever made, can take an angle in the Field nigher, if so nigh, as to five Minutes."

I have recently secured a copy of Prof. Van Ornum's paper on "Topographical Surveys,"* and am glad to ascribe to Watt the honor that seems justly due him in having been first to use subtense measurement in the construction-work on the Scottish canals. I had found a record of this fact,† but without dates or further detail.

From this Bulletin I wish also to supplement my remarks on the plane-table, and reproduce here the description and cut of the original instrument (mentioned on p. 690), for the benefit of the many who have not had the pleasure of reading the paper. Prof. Van Ornum says, in part:

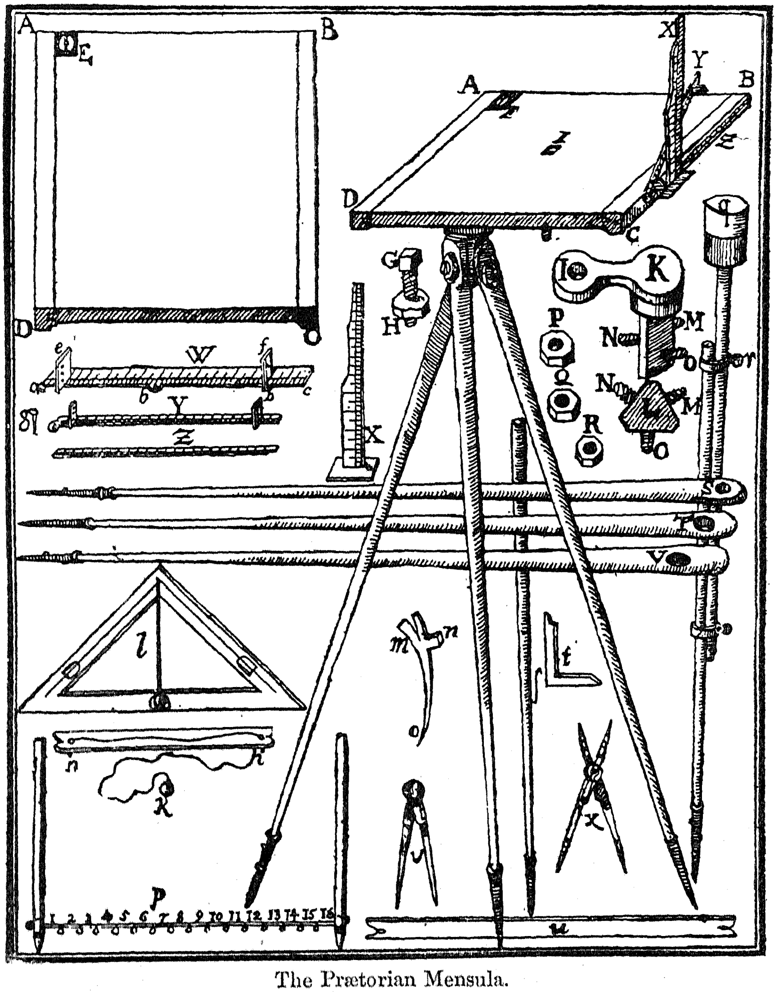
"To Johann Prætorius, the renowned mathematician, professor and savant, prolific in writings and inventor of many mathematical instruments, is definitely credited the invention of the plane table in 1590. To enable the engineer to understand the famous Prætorian Mensula, and to appreciate its peculiarities and principles of construction, Prof. Carl Dziatzko, of the University of Göttingen, Germany, has sent the accompanying cut (Fig. 61) and description, which were taken from M. Daniel Schwenter's *Geometria Practica*, Nürnberg, 1667. A B C D is a plane board about 15 inches square and 1 inch thick, having two cleats on the edges to prevent it from warping. In the corner is a compass, E, in a square box, having a sliding lid, so that it can be opened and shut at pleasure. A spirit-level (not shown) is necessary. G is a wooden screw, the bottom threaded, and the top

* *Bulletin of the University of Wisconsin, Engineering Series*, vol. 1, No. 10, Dec., 1896, pp. 331–369.

† *Inventors and Discoverers in Science and Useful Arts*, John Timbs, F.S.A., N. Y., 1860, p. 287.

having a square head. There is a nut, H, at the bottom. In the center of the board is a square hole, into which the wooden screw G is glued. K I is a hard-wood piece, with a round hole at I, through which the screw, G H, passes. To K a triangular piece, L, is nailed. On three sides of this piece three wooden screws, M, N, O, are glued, and three nuts, P, Q, R, made for them. Three pieces, S, T, V, 5 to 5½ feet long, are made to fit these screws, M, N, O, thus forming the tri-

FIG. 61.



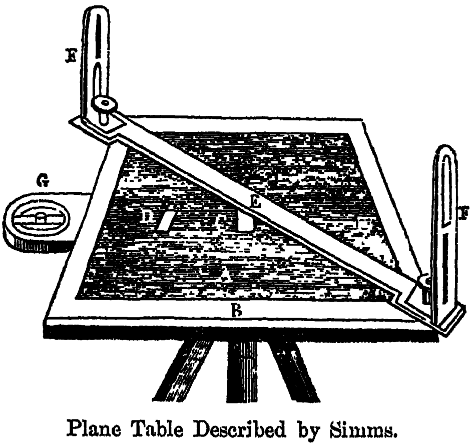
The Prætorian Mensula.

pod. A graduated brass scale, W, 14 inches long by 1 inch wide, forms what is called the chief scale. A semicircular piece of brass, *a*, is left at one end, and a hole made in it on the edge of the rule so that a fine needle can be passed through it. Six inches from this a similar piece, *b*, is left. Two sights, *e* and *f*, are made. The sight *e* has three fine holes perpendicular to the edge of the scale and in a plane with it. The sight *f* has a hole cut in it, and a fine wire or thread stretched

across it in the plane of and perpendicular to the edge of the scale. These sights are made so that they can be turned up or down. Three other brass rules, X, Y, Z, similarly graduated, are called the side rules. The first rule, Z, is ⅝ of an inch wide and 1 foot long, and is fastened rigidly to the cleat B C, so that the edge of it is in the middle of the cleat. The second rule, Y, is similar to Z, but has, besides, a semicircular piece of brass fastened to one end, with a hole in it. A screw, *g*, fits in this hole and the rule is fastened to the cleat B C, so that it coincides with the rule Z. This rule turns about the screw *g*, and has two sights, the same as the chief rule. The third rule, X, is 9 inches long and is soldered to a square piece of brass, so that when it is fastened to the table it will be perpendicular to the rule Z. The point where the top edge of Z crosses this rule is taken as the zero of its scale. A rule, *n i*, with the plumb-bob *k* attached, is used for centering the table over a point in the field. A target, *q*, *r*, *s*; triangle, *l*; square, *t*; measuring rod, *p*; hammer, *m*, *n*, *o*; compass, *v*; proportional dividers, *x*; and rule, *u*, complete the secondary equipment."

Such instruments as this were doubtless the first to be used in the Swedish mines; and where I have said (p. 691) that they were rude I wish to substitute the assertion that they were very complete, if we may judge by the little room there has been found for improvement up to comparatively recent times.

FIG. 62.



Plane Table Described by Simms.

In the latter part of the eighteenth century Mr. Beighton had used a plane-table with a telescopic alidade, in which the telescope was placed at one end and a counter-weight at the other. The instrument shown in Fig. 62, which is taken from a standard English work,* represents the construction in general use about 1840. The author says:

"It is a board, A, about 16 inches square, having its upper edges rabbeted to receive a box-wood frame, B, which being accurately fitted can be placed on the board in any position with either face upwards. This frame is intended both to stretch and retain the drawing-paper upon the board, which it does by being simply pressed down into its place upon the paper, which for the purpose must be cut a little larger than the board. One face of the frame is divided into 360° from

* *A Treatise on Mathematical Instruments*, F. W. Simms, F.R.A.S., London, 1834–1844.

the center, C, fixed in the middle of the board, and these are subdivided each way as minutely as the size of the table will admit. The object of these graduations is to make the plane table supply the place of the theodolite, and an instrument formerly in use called a semicircle.

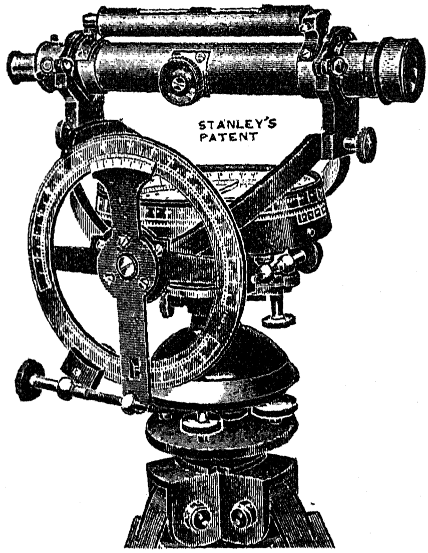
"There is sometimes a second center-piece, D, fixed on the table at about one-quarter of its width, from one of the sides and exactly half its length in the other direction.

"To the under side is attached a center-support with ball-and-socket or parallel plate-screws, by which it can be placed upon a staff-head, and made to sit horizontal by means of a circular spirit-level."

The author says, further, that the box-wood frame and its graduations could be dispensed with entirely, and that the expedition with which certain field-work may be performed by a person who is expert in its use is its chief recommendation.

W. F. STANLEY* (communication to author): I wish to acknowledge with thanks a copy of your article, and to express my pleasure with the extent of your research. In the preparation of my work I spent some months along these lines, but only partially succeeded; therefore, I know the trouble. What you have said concerning Fig. 40 I believe to be indisputable facts, but I beg leave now to submit a description of an instrument (Fig. 63) which I completed in the latter part of last year (1898), just as your paper was going to press. It is the first dial of the Hedley style, I believe, which may be used for sighting in true verticality. The Hedley ring did not permit this; but, by remodeling into a sort of cradle, this difficulty is avoided. The vertical limb is now a complete circle, and graduated to read on the upper half from 0° to 90°, in minutes of arc, each way. In the lower arm of its vernier is

FIG. 63.



Stanley's Latest Improved Hedley-Dial.

* Math. Instrument Maker, 4 and 5 Gt. Turnstile, London, England.

an index, which is used to indicate the correction in hypothenuse and base, as marked on the lower half of the circle.

The horizontal limb is graduated outside, as shown, and reads to minutes by double opposite verniers, placed so as to be coincident with the line of sight.

The diaphragm of the telescope is provided with platino-iridium points for subtense measurement, as described in my work,* p. 128. This alloy has about the hardness of spring-tempered steel, and is, as far as known, perfectly non-corrosive in air or moisture. We have found that this point-reading is more exact than with the web, as irradiation, due to the edge-reading of the web, is entirely avoided.

The growing sentiment in England is greatly in favor of 3 leveling-screws, but I do not think mine-surveying so exact as surface, and the strain put upon the axis by the use of 4 leveling-screws is unimportant, and otherwise much minimized by the springiness of the Hoffman-Harden tripod head. The great difficulty with our engineers here is to get head-room in the shallow workings of our coal-mines, and it was for this reason that I designed the prismatic dial you have illustrated in Fig. 41.

On account of its apparent height your mine tachymeter would not be received favorably in this country. The dial here described has been built as low as the conditions will permit, and seems to answer in many mines, though, as I say, there are obvious reasons why it should be still lower. Its total height, including the 3¼-inch tripod head, is 10 inches, and it weighs 8½ pounds.

Mr. Scott: The height of my instrument is not so great as it would seem by a casual inspection of Fig. 56. The standards are purposely made a little higher than is usual, so that, with a full aperture of the telescope, it can be made to observe objects in dips up to about 55°, and as great as 63° with about one-quarter of the diameter of the objective above the plates. They are, however, no higher than is necessary to effect conveniently the complete revolution of the 9½-inch main telescope and the partial revolution with the 5½-inch auxiliary telescope

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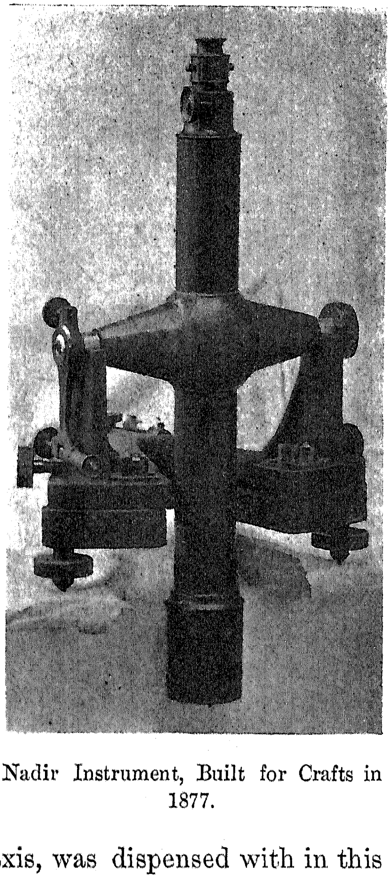
* *Surveying and Leveling Instruments*, W. F. Stanley, London, 2d ed., 1895.

attached. When the interchangeable auxiliary is placed on top, the total height from the tripod-head in the 5-inch model is 14 inches, and the total weight 12 pounds, or 5.5 kilogrammes.

C. L. BERGER & SONS* (communication to author): After much difficulty and delay we have been enabled to secure a photograph of the nadir instrument (Fig. 64), to which you have referred on p. 701. It was designed by our Mr. C. L. Berger to carry the alignment of the Dorchester Bay sewer very accurately down through the westernmost of the three shafts sunk upon it in driving its entire length of 6090 feet. The lower part of the cast-iron stand rests upon three supports, the two forward being contrived to act as leveling-screws, the rear one being merely a stationary swivel-point upon which the upper part is made to move slightly in azimuth by means of the opposing tangent-screws shown acting against two small pillars near the base of the Y-standards.

FIG. 64.



Nadir Instrument, Built for Crafts in 1877.

When the desired position is thus attained, the base is clamped by means of the set-screws or nuts shown in the forward part on each side. The adjusting block, usually set into the bearing of the horizontal axis, was dispensed with in this case, as the adjustment could be secured by means of the leveling-screws and a delicate striding-level provided for that purpose.

The telescope had a 2-inch aperture, a focal length of about

* Math. Instrument Makers, Successors to Buff & Berger, 9 Province Court, Boston, Mass.

20 inches, and a power of about 40 diameters. As in all telescopes of this length and size, the focusing arrangement is placed at the ocular, where it is always within easy reach.

Mr. Stearns, in the paper to which you have referred, correctly said: "As the use of a vertical cross-wire would have caused confusion on account of its looking so much like the string, two wires crossing each other, and making a small angle with the vertical, were used instead."

The entire weight of this instrument is about 50 pounds.

F. W. Breithaupt & Sohn* (communication to author): We have studied very carefully the copy of your work which you sent us. We regret that we have no drawing of the first complete telescopic mine-theodolite made by us in 1832 for the Imperial Brazilian Mining Association of London.

The horizontal circle, however, was 5 inches in diameter, divided into $\frac{1}{2}°$ and read by verniers to 1 minute of arc, and the ocular provided with a prism for steep upward sighting.

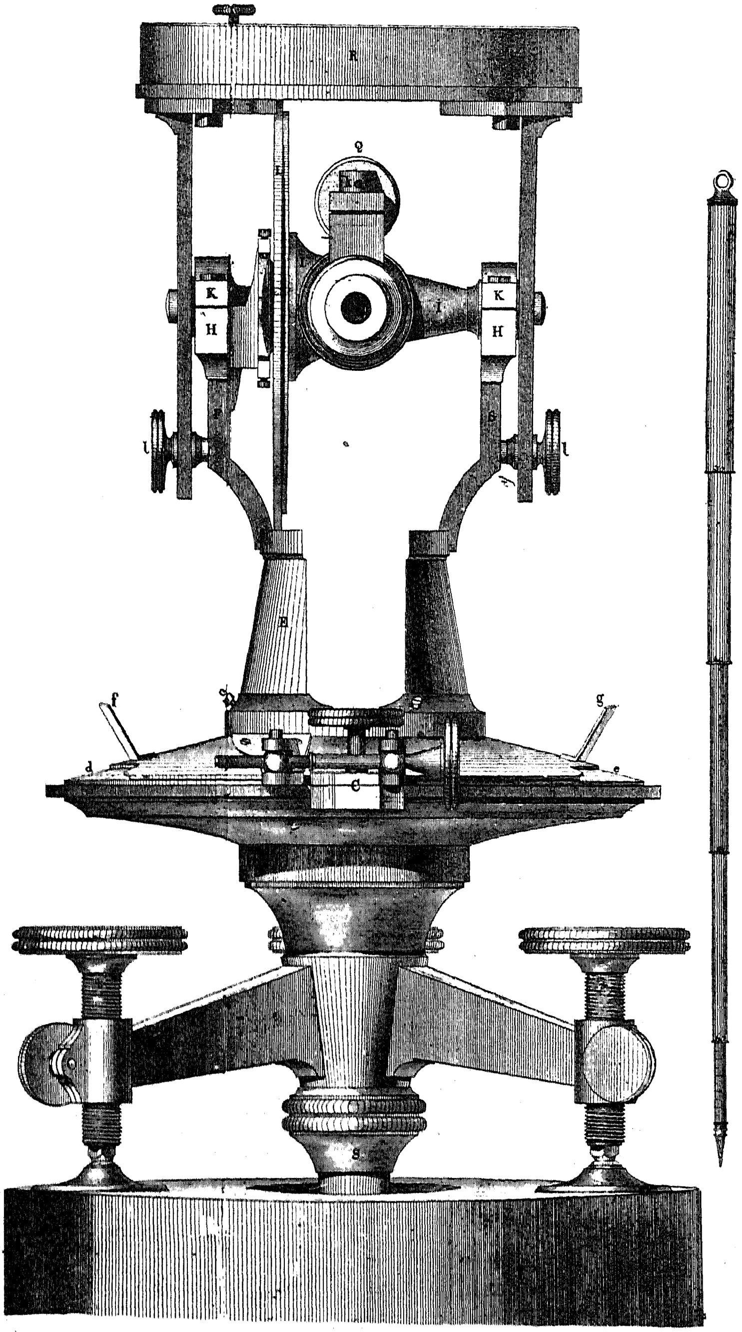
We send you a copy of the fourth volume of our *Magazin*, published in 1860, in which you will find illustrated a mine-theodolite (Fig. 65), the first of its kind in Germany, which we made for the Mine-Surveyor-General of Saarbrücken in 1836, and which Bergingenieur Praediger, in the same year, used in that celebrated survey of 2000 meters in the Ensdorfer tunnel at the Kronprinz coal-mines, near Saarlouis.

It will interest your readers to notice the apparatus provided to measure the height of the instrument above the station over which it is set.

It was made of five small tubes, one sliding within the other, so as to be convenient to carry about and quickly attached to the hook of the bar that passes down through the head of the tripod. In this position the bottom of the first tube was always 30 inches below the horizontal axis; the next, when pulled out its full length, 40; the next, 50, etc.; and, finally, the odd inches indicated on the last draw. We call attention also to the way in which the plummet was balanced by a counter-weight—a method that does not compare very favorably with the reel-plummets used in your country to-day. The tripods had exten-

* Math. Instrument Makers, Established 1760, Cassel, Germany.

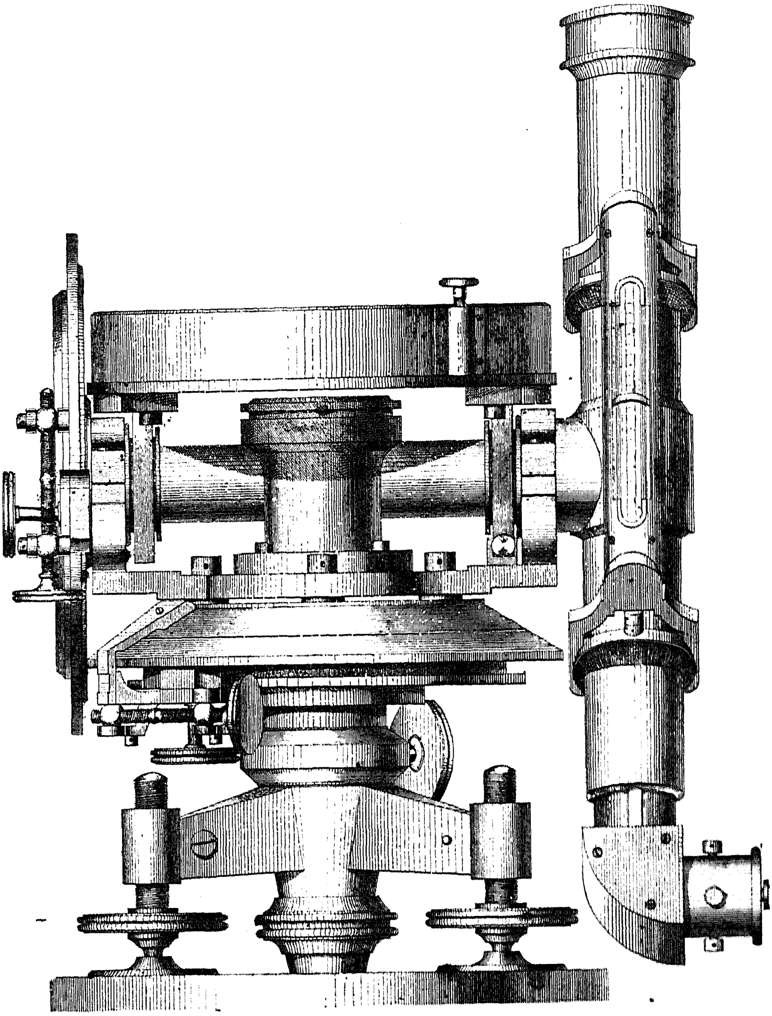
FIG. 65.



Praediger's Original Instrument of 1836.

sible legs, and the signal targets were so designed that their centers should correspond with the axis of the instrument in height.

Fig. 66.



Breithaupt's First Eccentric Mine-Theodolite.

In the same magazine is also illustrated the eccentric theodolite (Fig. 66) in its first form, as it appeared in 1834. Among the advantages claimed for it then may be enumerated:

1. It may be used to sight an object in any elevation or depression with the single exception where the object is exactly

vertical above or below the center of the instrument, and this difficulty can be obviated by a little shifting of the object or the set-up point. As a little disadvantage one could mention, the object must be sighted in two different positions of the telescope, unless a trigonometrical calculation is made to account for the eccentricity of the telescope; but this operation is not only convenient but absolutely necessary to compensate for the little imperfections in instrumental construction. All vertical angles are read without correction.

2. The far easier adjustment of the instrument.

3. Diminishing the height of the telescope's axis, which is only 2 inches above the horizontal plates.

4. Greater length of telescopic axis between its supports and larger diameter of vertical circle.

5. The construction is such that the bubble tube on the telescope can also be placed to stride the axis for its more accurate adjustment.

For convenience, the telescope had a prismatic ocular, and was provided with a reflector to measure altitudes of the sun, for which purpose this theodolite is well adapted. It is also convenient in sighting the polar star to establish the true meridian. The striding-compass and circular box-bubble are both on top of the instrument, and very easy to observe.

We cannot give any authentic information as to who first used this instrument, but in any event it is quite wrong that Borchers had used it as early as 1835, as you record it on p. 705. He was not employed at Clausthal until 1841.* At that time he found there, in the Royal Mining Academy, a theodolite of our make, which was not intended, or properly designed, for mine-surveying. With it, however, he conducted a mine-survey, the results of which were so satisfactory that he was led in March, 1842, to order a theodolite, which we delivered in May, 1844. We regret that we have no presentable illustration; but concerning it, we will say that the vertical circle was divided into $\frac{1}{3}°$ and read by opposite verniers to minutes. The horizontal circle was 6 inches in diameter, divided into $\frac{1}{3}°$ on silver and read by verniers to 30″. The vernier openings in the covering of the limb were provided with glass plates to

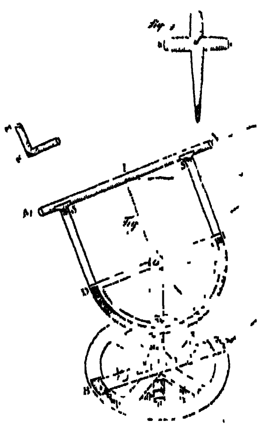
* See *Der Bergwerksfreund*, vol. xiv., p. 419.

protect them from dust, etc., the invention of which device must be credited to our house in 1835. The telescope was 13 inches long, was reversible upon its horizontal axis through the standards, and provided with a bubble-tube that could be turned to the line of sight. There was also a striding-compass, but the special feature was the reflector arrangement fixed to the objective, to which you have referred on p. 730 of your work. This reflecting mirror moved in a small graduated arc, upon which it could be clamped in any convenient or desirable position, and the exact value of the deflection-angle read by a small vernier provided for the purpose.

Borchers had this concentric instrument in commission until 1856. On June 10, 1850, the great Ernst-August tunnel was begun, and the first holing was made in 1856. Then, on account of the work to be done in inclined shafts, Borchers had an eccentric theodolite made by Meyerstein, very much as you have shown on p. 704.

PROF. DR. MAX SCHMIDT* (communication to author): As your work deals only incidentally with the catageolabium of Giuliani, I shall be glad to supplement it at your solicitation with the best description it has been possible for me to prepare in the short time I have had at my disposal for this purpose.

FIG. 67.



Prof. Giuliani's Catageolabium, 1798.

On p. 79, Section 91 of his work, Giuliani says:

> "If I were a mine-surveyor I would use an instrument shown in Fig. 2, Plate V. (here reproduced in Fig. 67), which corresponds in its principal parts with Brander's *Scheiben instrument*. I will call it *Catageolabium*,† as it serves for subterranean measurement."

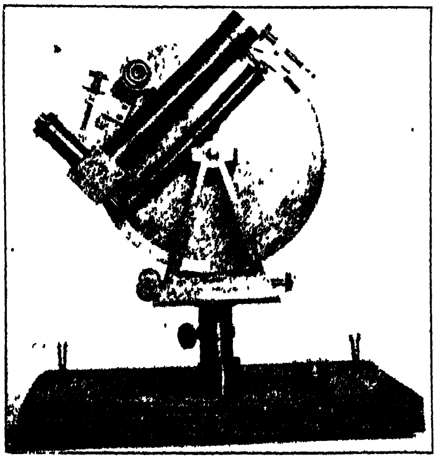
Here follows his description, from which it appears that the circle had a diameter of 14 or 15 inches and was divided into 24 hours of 60 minutes each. It had two verniers, by which the hour-minutes were divided

* *Vorstand des Geodetischen Instituts der Königl. Technischen Hochschule*, München, Germany.

† Constructed from the Greek words κατά, downward through, γῆ, earth, and λαβεῖν, to take or to measure.—SCOTT.

into 15 parts. On the alidade there was a small circular box-bubble and compass. The vertical arc was of 6-inch radius, and provided with one vernier, by which each degree of arc could be read to 2 minutes. Upon this vertical arc was a tube supported by two pillars of such length "that the tube can see beyond the plate in very precipitous angles" (this is, therefore, certainly the first top-telescope); "but the discomfort experienced with these precipitous angles by being obliged to hold the head so far back or so far forward over the plate in order to get the eye to the tube is avoided by unscrewing the front part of the tube and substituting another small tube bent at a

FIG. 68.



One of the Oldest-known Broken-Telescopes.

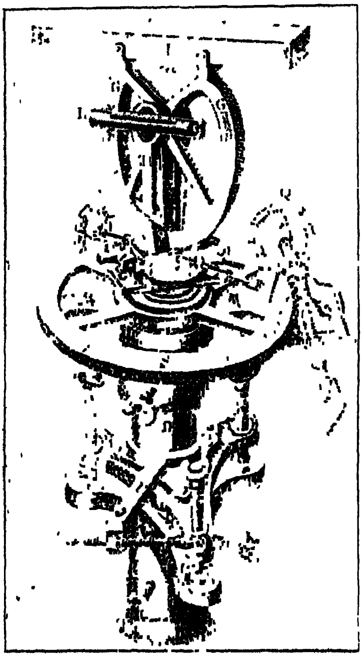
right angle and provided with a 45° reflector." (This is the first broken-telescope that I know of.)

Another very old broken-telescope is shown in the accompanying illustration (Fig. 68). It is one made by an unknown mechanic, though from the metal work and workmanship I should say that it came from the shop of Hoeschel—the son-in-law of Brander—somewhere between the years 1800 and 1810. The objective is achromatic and of Fraunhofer's design. The instrument consists of only a vertical circle, a broken-telescope and a telescope-bubble of Brander's pattern. It is now in the possession of the geodetic department of the Royal Technical Academy (*Hochschule*) of Munich.

Another of the earliest types of these instruments which I have in my collection was probably made by Utzschneider & Fraunhofer, but in what year I do not know. The striding-bubble it now possesses has been added recently, as well as the micrometer-screws and verniers of the vertical circle. But the telescope, the horizontal circle, the tripod base and the arms which support the reading-glasses remain unchanged.

I send also another illustration (Fig. 69) of the *Scheiben instrument* of Hoeschel as modified by Oberbergrath von Voith in A[illegible]berg. and described in his work.* The illustration shows a theodolite of Hoeschel as it was duplicated in 1792, for the Bavarian Academy of Science, for a land-survey. To adapt this theodolite for mine-surveys, von Voith (in 1805) replaced the telescope with a diopter-tube, while the micrometer-screws for the measurement of angles remained unchanged.

Fig. 69.



Von Voith's Theodolite.

This instrument was also provided with a single vernier at one end of an alidade, or arm, at the opposite end of which was the clamp and tangent-screw. For mine-surveying there were provided signal-lamps, in which the rectangular window was marked with a cross. Brander's bubble-tube (which was hinged at one end and provided with double-adjusting nuts at the other) occurs again on the vertical arc. To set up the instrument in the mine, v. Voith used the Hungarian surveying-buck.

Komarzewski's instrument is described and illustrated in the *Journal des Mines, No.* 48, *Fructidor, An XI* (1803). *Rapport fait*

* *Vorschläge zur Vervollkommnung der Markscheiderinstrumente,* Ignaz v. Voith, Landshut, 1805.

à l'Institut National des Sciences et des Arts sur un Graphomètre souterrain destiné à remplacer la boussole dans les mines, as well as in the little work entitled *Mémoire sur un Graphomètre souterrain* (*à Paris chez Charles Pougens*), which says that the instrument is constructed upon the same principles as the theodolite, and consists of a circular disk, which is placed firmly and in a horizontal position by means of a level with a cylindrical air-space.

But the illustration is nothing else but the *Eisenscheibe*, as it is portrayed in von Oppel, and as it was improved by Studer in Freiberg, for the measurement of vertical as well as horizontal angles, "under the instructions of Krumpel," in 1792.* Komarzewski made surveys in the mines of Freiberg with this instrument between 1795 and 1801.

Borchers, while a mining engineer in Clausthal, wrote† that in France mine-surveys were made about 1835 with a theodolite with eccentric telescope. Reference may be made also to an article by Prof. Combes, *Annales des Mines*, Series 3, *Tom.* ix., 1836, and to the separate edition, published in the same year, and entitled *Sur les levés de plans souterrains*, etc.

The theodolite as a mining-instrument was described and illustrated in the work of von Hanstadt in 1835; but in the *Bergwerksfreund*, vol. 14, p. 392 (1851), the Royal Prussian mine surveyor of Saarbrücken says that the use of the theodolite had been established in the mines there since 1817. The official records of that district show with certainty that Praediger used a theodolite there in 1835. Two theodolites of this kind, ordered from Breithaupt by the Royal Prussian Ministry of the Interior, were described by Praediger in the *Bergwerksfreund* in 1836.

In the work of Gensanne‡ is described the *Recipiangle ou Graphomètre*, which, according to the illustration, consists of a half-circle with one set of fixed and one set of movable sights, so that it is nothing else but an astrolabium. Again, the work of Duhamel§ describes a method entitled *Lever de plan d'une Mine avec le Graphomètre*, etc.

* *Freiberger gemeinnützige Nachrichten*, 1803, p. 189.

† *Bergwerksfreund*, vol. xiv., No. 40, 1851.

‡ *Géométrie Souterraine*, M. de Gensanne, Paris, 1770; Montpellier, 1776.

§ *Géométrie Souterraine*, J. P. F. G. Duhamel, Paris, 1787, p. 179.

The solar apparatus shown in Fig. 54 was first made in Germany by Hildebrand of Freiberg, on an order of Bergingenieur Keller, who was then in America, but with improvements suggested by me.*

MR. SCOTT: Dr. Schmidt may be correct in ranking Giuliani's instrument as the first of broken-telescopes, but I must differ with him in the assertion that in it is to be found the first *top*-telescope; for while the sighting tube occupies the same relative position it is in no sense an auxiliary device, or what the Germans call *Hülfsapparat*. There is a distinction between an eccentric main telescope and an eccentric auxiliary telescope, and in this comparison it does not matter whether the eccentricity occurs at the side or above the center of the instrument. The sighting-tube of Giuliani's instrument is no more to be considered a *top*-telescope than that shown in Fig. 66 is to be considered a *side*-telescope. I could also question the statement, but not with the same degree of assurance, that the sighting apparatus in the *Catageodiabium* is a broken-telescope at all. It seems to be a simple application of a prism to the eye-piece. In the common acceptation of the term, as I understand it, a broken-telescope is one in which the prism is placed between the ocular and the objective, as I have it in Fig. 68. There seems to be a prevailing opinion that the invention of the broken-telescope belongs to Reichenbach. T. Ertel & Son, his successors, in writing to me, doubtless with reference to the instrument mentioned by Prof. Schmidt (p. 948) as "another of the earliest types," say:

"Since our present manager came to the direction of our business he has been able to discover only one of Reichenbach's instruments, which we sold to the Royal Technological Academy. As nearly as could be judged by its appearance it must have been made some time in the first twenty years of this century, but we are not certain that this was the first of its kind."

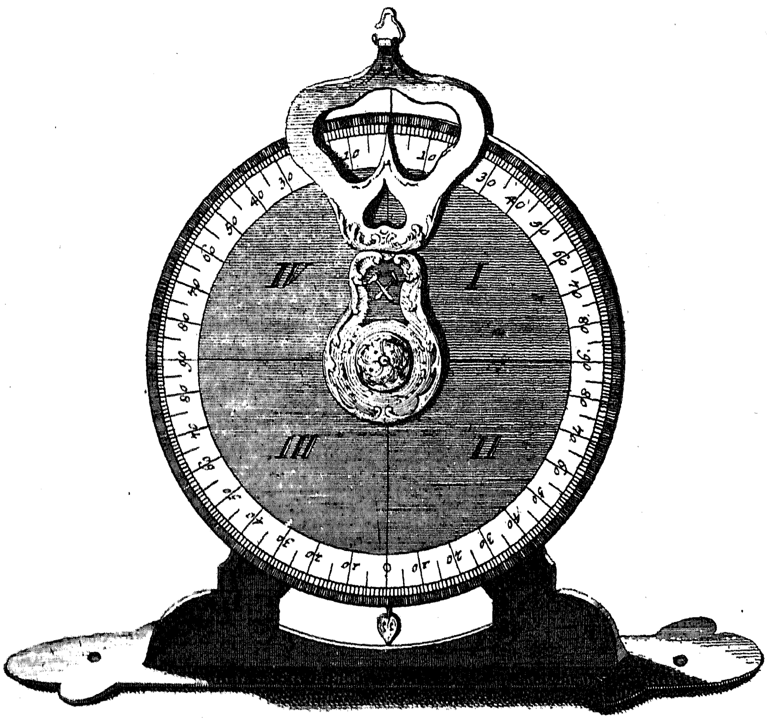
Illustrations of the *Eisenscheiben* of von Oppel, to which Dr. Schmidt has referred, I reproduce here (Figs. 70 and 71) from my copy of this justly celebrated old work.† On pp. 207–212 he seems to say, in part:

* *Zeitschr. für Instrumentenkunde*, vol. viii., p. 188.

† *Anleitung zur Markscheidekunst*, F. W. von Oppel, Oberberghauptmann in Dresden, 1749.

"I divide the *Eisenscheiben* into two principal kinds, those that give the angle in the common degree of the circle and those which express it in hours, etc. The first kind (Fig. 70), which is graduated into 360°, I propose to make as follows: Take a circular brass plate and divide it into four quadrants, each of which is marked with a Roman numeral, as is shown, for distinction. Each quadrant is divided into degrees and numbered each way from the principal zero-line, which is engraved upon the back of the plate as well as upon its face. The index-arm must now be pivoted at the center in perfect concentricity with the plate, and at its outer extremity provided with a ring or hook, to which the measuring chain may be conveniently attached. Then make a stand, the base of which can be screwed to a desired station, and mount the plate upon it by two hinges, so that it

FIG. 70.



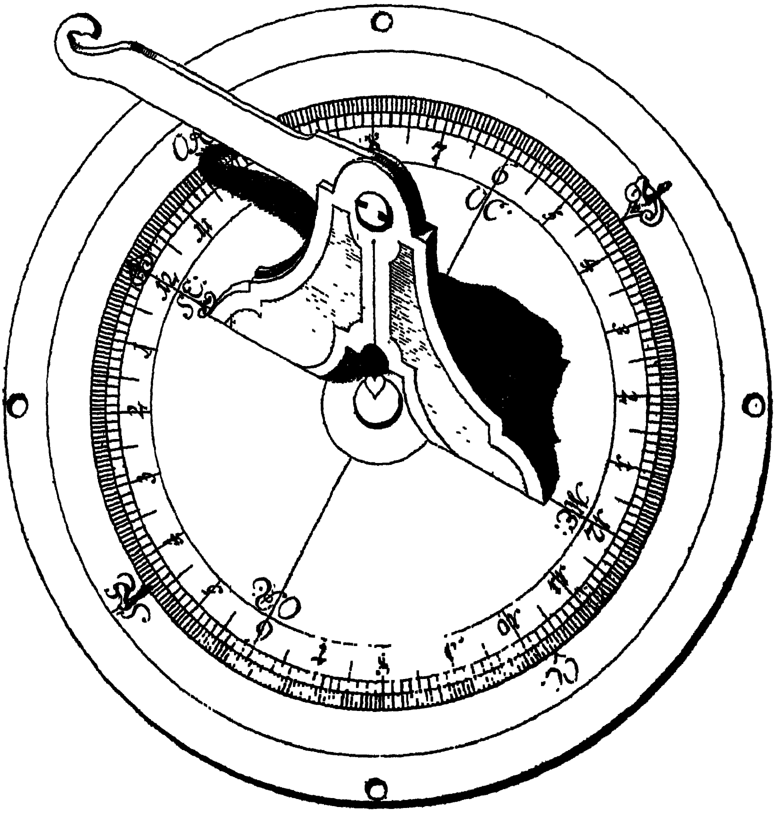
Von Oppel's Eisenscheibe, Style No. 1.

can revolve, if necessary, to a horizontal position upon the 90°-line. If the small plummet line, which is attached to the center of the upper part of the base, always coincides with the meridian-line that is engraved upon the back, the base will be perfectly horizontal.

"The *Eisenscheibe*, which is divided into hours (Fig. 71) and the subdivisions thereof, I recommend as being just as convenient for use. In a solid brass circular plate, which is hollowed out for the purpose, is inserted a smaller graduated disk, as well as a ring surrounding it, each of which may be revolved about a common center at will without disturbing the position of the other. In the graduated circle the cardinal points (Meridies, Septentrio, Occidens and Oriens) are marked in reversed position as in the compass, and upon the 12th-hour line is securely fast-

ened a strong brass plate, standing perpendicularly upon it, and holding a brass indicator-arm provided with a hook at its outer end, to which the brass measuring-chain may be attached. The intermediate ring is divided simply into quadrants, and upon its meridian-line are two small blue steel pins to aid in moving it upon a back-sight, where it is clamped by means of small brass pins from beneath. Through the outer plate are bored a few holes, so that the instrument can be securely screwed to any station-point. On each side of the vertical plate are suspended small plummets, which determine the horizontality of the setting."

FIG. 71.



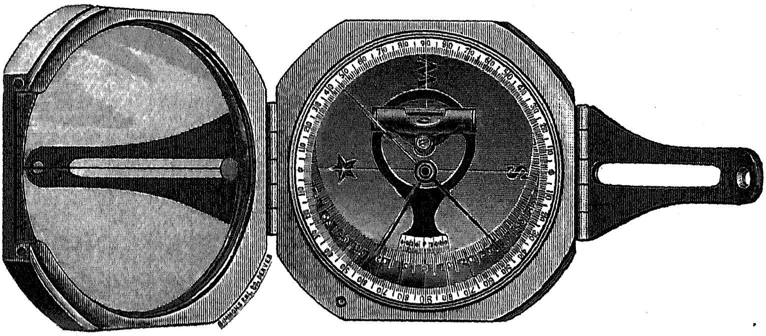
Von Oppel's Eisenscheibe, Style No. 2.

D. W. BRUNTON, Denver, Colo. (communication to the Secretary): I have read with care Mr. Scott's most interesting paper, and regret that I have not time to discuss at length some of the many questions it suggests.

In Aspen, Leadville, and Red Cliff, Colo., and generally in western mining camps where contact ore-bodies occur, and strip or vertical veins are almost unknown, the favorite (and, to my mind, by all odds the most convenient) instrument is

Buff and Berger's new high-standard mountain and reconnoissance transit, with a 4-inch horizontal limb, weighing 6 pounds. In this instrument the tangent-screws are placed at one side, away from the line of sight, and the edge of the horizontal arc is notched as deeply as possible without cutting through the metal. This arrangement, combined with the greater elevation of the standards, permits angles of either elevation or depression up to about 70° to be read with the ordinary telescope. This is as far as it is ever necessary to go in this region, except on shaft-work, which is always done by plumbing. The great practical objection to instruments with top or side auxiliary telescopes is not that they cannot be brought into adjustment, but that, being elaborate and expensive, they must be carefully

Fig. 72.



Plan of Brunton's Pocket-Transit Opened for Taking Courses or Horizontal Angles.

kept, and therefore are frequently in the office, perhaps several miles away, when occasion for their immediate use arises.

At the request of the Secretary, I take pleasure in contributing to this discussion an account of my pocket mine-transit,* manufactured by William Ainsworth & Son, Denver, Colo., and already in use in every country from Australia to Alaska. It is employed in the work of the United States Geological Survey, and the surveys of most of the States and of Canada. Instruction in the use of it is a part of the engineering course at the Lawrence Scientific School, Harvard University, the School of Mines, Columbia University, and a number of the western mining schools. The chief merits of this instrument consist in

* Patented September 18, 1894.

its extreme portability and the extraordinary rapidity with which reasonably accurate surveying can be performed by its use.

Many years ago I began experimenting with the purpose of devising a combination-instrument which would perform all the necessary survey-work required for current daily mining practice and commercial and legal mine-examinations. After constructing six or eight different forms, I hit upon the design now finally adopted, and made arrangements for its manufacture with the house above named. The development and introduction of this instrument has been with me a labor of love, and not an enterprise looking to commercial profit; and the same is, to a considerable degree, true of the manufacturers, who use the utmost care in the production of the instrument, and push its sale largely as an indirect advertisement of their chief business, namely, the manufacture of instruments of precision and high-class balances, in which latter line they have already surpassed nearly all competitors, and achieved the command of the American market.

Fig. 73.

Correct Position in Taking Courses or Horizontal Angles not more than 45° Above or 15° Below the Observer.

The dimensions of this pocket-transit are $2\frac{3}{4}$ by $2\frac{3}{4}$ by $\frac{15}{16}$ inches, and the weight (in aluminum case) is 8 ounces. In other words, it is strictly a pocket-instrument, and is, in fact, carried in the pocket like an ordinary compass, which it does not exceed in bulk. Yet it does the work of a sighting-compass, a clinometer, a prismatic compass, and an Abney or Locke level, measuring horizontal and vertical angles, dips, etc., with a high degree of accuracy.

I will not enter into detail here as to the manner of its use for all these purposes. The manufacturers will furnish on demand a circular covering these particulars, and a few general remarks will be sufficient in this place.

Fig. 72 is a plan of the transit when opened for taking courses or horizontal angles. It shows a spirit-level, which should be set, for this operation, at right-angles to the line of sight.

Fig. 73 shows the proper method of *holding* the instrument in taking courses and horizontal angles.

The instrument is correctly sighted on the object when the eye, looking into the mirror which lines the lid, sees the black center-line bisecting both the opening in the front sight and the object sighted at; after which, the reading of the needle is comparatively easy if the proper precautions as to position and leveling have been observed. The most important of these is, that the instrument should not be turned in the hands, as is customary with an ordinary compass, but the hands should be held rigidly against the body, which should serve as a tripod for the instrument, and changes of direction should be made by twisting the body to right or left, preserving the level position as indicated by the bubble.

For inclined sights and for taking dips, the bubble-tube (which is easily revolved, by means of a crank on the back of the instrument, with the middle finger of the right hand, while the thumb and fore-finger grasp the instrument) furnishes an accurate reading by means of the vernier attached to it (Fig. 72) and revolving with it.

A little practice will enable the engineer to perform with this small pocket-transit work of great variety and surprising accuracy at very little cost of time. In many cases, such a small and portable instrument will be to the engineer a most agreeable change from the numerous old-fashioned contrivances which it supplants.

H. D. Hoskold, Buenos Aires, Argentine Republic, S. A.* (communication to the Secretary): The writer is not aware that any record exists indicating the period when angular and linear measurements were first introduced and practiced as a science, and the form of the instruments employed as auxiliaries in useful astronomical observations and engineering operations for scientific and economic purposes. Still, as previously stated,† he believes that the first instruments were exceedingly rude in construction, and probably consisted for the most part of two

* Director of the National Department of Mines and Geology and Inspector General of Mines of the Argentine Republic. This communication was received May 5, 1899.

† *Trans. Am. Soc. Civ. E.*, vol. xxx., p. 137, 1893.

movable cross-bars of wood or metal fixed on the top of a rod, the opposite end of which was thrust into the ground for use; or some such contrivance may have been placed on a square board in the form of a plane-table. The angles observed and formed by the radial bars may also have been determined in linear measure by applying a simple straight-line divided scale of equal parts, similar in principle to that which was applied to the cross-staff of navigators in 1514,* or by the divided sides of a quadrilateral figure or geometrical square described upon a board.

Nevertheless, in the Chaldean records, recently discovered, mention is made of an *iron wheel* (or circle) constructed some 4000 or 4500 B.C.; but nothing is said about its use. It is important to note that the late Mr. George Smith, of the British Museum, discovered, prior to 1870, in the ruins of the tile-brick library in the Palace of Sennacherib (704 B.C.), a large fragment of a circular Assyrian astrolabe, the circumference being originally divided into 12 equal parts, corresponding to the signs of the zodiac and months of the year. It had, also, an inner circle, and in each division the principal or prominent stars are found. This instrument is at least 2604 years old, and probably the oldest on record.

The ancient astronomers (date unknown) employed copper circles of large diameter placed in the meridian, as also at right angles to that line;† but we have no evidence how they were divided. Astronomical and other observations were practiced, it is said, in Egypt 3000 B.C.; as they were also in China 2700 B.C., if Chinese history is worthy of credence. A Chinese emperor, Hwang-ti, is said to have invented the cycle of 60 years, 2600 B.C.‡ He has also been credited with the invention of various astronomical instruments, including one for observing the four cardinal points, which is generally considered to have been a magnetic compass;§ but it was more probably a circumferentor. It is recorded that early Buddhist astronomy possessed instruments made of brass; but their inferiority and mode of use caused them to give place to larger ones, enormous

* *Life of the Navigator John Davis* (1578), p. 145, 1889.

† J. S. Bailly, *Histoire de l'Astronomie Ancienne*, 2d ed., 1781, p. 13.

‡ Davis, *History of China*, vol. i., p. 219, 1857.

§ J. S. Bailly, *op. cit.*, p. 121.

instruments built up of masonry, the divided portion, or arc of the circle, being of marble. With these instruments, angles were measured to single minutes. In 1729 such an instrument existed in Delhi, and a degree upon its divided limb was measured equal to $2\frac{5}{6}$ inches. Claudius Ptolemy, in the second century, possessed similar instruments, as also the astrolabe, with four circles placed in different planes, which had been invented, some 300 years before, by Hipparchus, the greatest discoverer in mathematics, astronomy, geography, etc., of ancient times.

From what has been brought forward, it cannot be fairly argued that the ancients may not have possessed portable circular instruments for rough land-observations long prior to the times of Hipparchus, Ptolemy or Sennacherib. Unfortunately, however, the infamous and ever-to-be-lamented destruction of the Alexandrian libraries, an incalculable loss to the world for all time, has placed it out of our power to determine the particular form, nature and size of the instruments used during the earlier ages. The sculptured and painted figures recently discovered upon the walls of a copper-mine at Wady Magerah, which was worked under the reign of the Egyptian King Senefura, 4000 B.C., and also the map of an Egyptian gold-mine from 1400 to 1600 B.C., afford strong inferential evidence that mine-surveying was known and practiced at a very early period of the world's history. From that period to the time of Hero and Euclid—also improvers of instruments and the science of surveying—little of importance is known relative to such matters; neither have particular details come down to us regarding the instruments and mode of surveying adopted during the earlier Greek and Roman mining period. Even the great Roman engineer, Antoninus, does not appear to have employed any angular instrument in determining the direction of the various lines of roads measured by him in the nations conquered by the Romans. It is highly probable that mine-surveying was forgotten more or less, or hid in obscurity for several centuries, as a forbidden art, or suspicious dark practice.

Tradition affirms that the first mode of performing surveys in mines in England involved the use of a low, three-legged stool, like a small plane-table, a chalked string, some kind of measure, and a book for entries. It seems that the plane-table

was fixed at the end of the first bend in the underground road, and the string, held in the direction of the road leading back to the shaft, was then raised a little by the forefinger and thumb, and let fall suddenly, producing upon the table a chalk-line, a portion of which was erased to leave room for succeeding lines. The string was then stretched in a forward direction and treated as before, the measure of the lines being entered in a book, as also the number of the chalk-lines. At the second bend in the road the last preceding forward line was brought into the direction of the last piece of road measured, and the string stretched in a forward direction. Thus a kind of rough traverse-plotting was carried on underground. Undoubtedly, however, that plan of surveying must have been limited to a few lines. It is also probable that such surveys were made with the purpose of repeating them at the surface; and, if so, the direction of the first line in the underground working must have been determined by suspending two lines down the shafts, which, in those early times, were very shallow. When the writer was a boy he heard an old miner of eighty-four make this statement, and the old man had heard it from his grandfather. Whether this plan of surveying is older than Agricola, 1546; Digges, 1571; or Houghton, 1681, cannot be determined; but it is highly probable that it preceded the latter, and continued to be employed after he wrote his work on *Surveying of Mines*. This mode of the three-legged stool may also have given rise to the old-fashioned land-surveying plane-table.

It is on record that the "good ship Plenty" sailed from Hull in 1338, directed by the mariner's or sailing (magnetic) needle; so that a rough magnetic compass could have been employed in England for mining and other surveys previous to the time when Agricola wrote; but there does not seem to be any actual proof that such was the case during the long interval which elapsed until the time of Houghton.

Quadrants and plane circular astrolabes, the one divided into 90° and half of the other sometimes to 180°, for measuring the elevation of the sun and stars at sea and on land, existed at an early period in the East, in Spain, and in England. The former had plain sights attached to one side, with a plumb-line to mark the angle. The circular instruments had plain sights attache

to a radial bar, revolving around the circumference in the same manner as in Digges's *theodelitus.* Such quadrants and astrolabes were sometimes suspended by a ring in the vertical plane of the object to be observed. Two such instruments as those described, of small diameter, are represented upon the second original Borgian Map of the World, by Diego Ribero, Seville, 1529, which map is preserved in good condition in the museum of the Propaganda at Rome. The instruments referred to are divided to single degrees, and, in that respect, are superior to the *theodelitus* of Digges; the parts of a degree were estimated. An exceedingly curious ancient magnetic compass, with five divided circles, is also engraved upon that map. The instruments of Ribero were of a common type, used long before and after his time, and they present sufficient evidence to prove that these were the models from which the compass of Agricola, 1546, and Digges, 1571, and others were derived. The astrolabe, in fact, in its simplest form was a plane circle (in contradistinction to that with four circles in different planes, sometimes divided half-way round, and sometimes entirely so), and, consequently, must have been used for land-surveying exactly in the manner described by Digges. At the International Geographical Congress, London, 1896, the authorities of the British Museum exhibited a number of astrolabes—the earliest being one made in Toledo, Spain, in 1067. There were also one made in Valencia in 1086—evidently derived from Moorish or Arabian sources—and one made in Cairo, 1240, as well as one made of brass, in England, in 1260, and one formerly belonging to Sir Francis Drake, 1570, besides various others of the fourteenth century and succeeding dates.

With the exception of the omission of some types of surveying instruments, Mr. Scott has fairly represented in his paper the progress made in various countries in the construction of instruments for the object under discussion. In the copy of Digges's second edition, 1791, in the possession of the writer, Chapter 27, there is a diagram of his 2-foot surveying circle—*theodelitus*—a copy of which was sent to Mr. Scott. We cannot suppose, however, that a circle of so large a diameter was commonly used in mines; still, it could have been so employed. Nothing would be gained by following Mr. Scott in detail, because he has done his work so well.

It would appear, however, that little improvement was made in land- and underground-surveying instruments up to the time when Ramsden completed, about 1760, the grand invention which he applied in practice during the period from 1784 to 1799. Others followed, some time prior to 1788, in Germany, and also probably in France about 1790. As far back as 1804, Fenwick, a celebrated surveyor and colliery viewer of Durham, England, proposed the plan of a "fast needle," as he termed the *circumferentor* or rough theodolite-limb, constructed in his time. Still, he had to depend upon the magnetic needle to obtain the bearing of some selected line in the survey. Fenwick's book contains a complete system of magnetic-compass or dial [illegible] and, so far as that system is concerned, it has not been, nor will it ever be, superseded.

Various opinions had been emitted from Fenwick's time up to 1842, when Butler Williams,* a prominent English civil engineer, suggested the necessity of improving the theodolite and adapting it more generally to mine-surveys. He also wrote a very concise and exceedingly useful chapter upon underground surveying, suggesting the use of three tripods, as also a system of plotting underground surveys by co-ordinates. Combes and D'Aubuisson had formerly attempted to introduce some such plan; still, such was the opposition and obtuseness of that period, that the miners' dial in some form or another was, and still is, continued in use for mine-surveying. Various authorities have stated that the writer was the first in England to publish, in 1863, a general system of mine-surveying by the sole use of the theodolite. That work advocated plotting underground surveys by the co-ordinate system, and for this and other useful purposes a complete set of traverse-tables formed part of the work alluded to.†

Although no account of the miners' transit-theodolite (Fig. 74) was published earlier than 1863, still the writer believes that he had it in use prior to 1858. By means of a long diagonal eye-piece, the instrument was intended to be used for connecting underground workings to the surface by direct sighting up a shaft, and fixing an illuminated wire in the same direc-

* *Practical Geodesy*, B. Williams, C. E., pp. 207, 219, 1842.

† *Practical Treatise on Mining, Land and Railway Surveying and Engineering*, London, 1863.

tion as the first drift underground. In deep and wet shafts this plan was impracticable; but in shallow dry pits, when the operation was performed on dark nights, fair success was obtained. For deep pits, the writer found that two chains made in a particular form of steel wire of different sizes, to support the weight suspended down a shaft for determining the direction of the first line in the underground survey, were completely satisfactory.

The theodolite, Fig. 75, was designed soon after that represented by Fig. 74; but it was not constructed until about 1862–63, and an account of it was published in 1865.* However, some defects had been introduced in the construction, and being pressed for time, the writer did not attend further to the matter until 1889, when Troughton & Simms made some alteration in the instrument, making it as represented in Plates I. and II. of the writer's paper, published in 1893.† That firm also constructed a new instrument of the same class as that under consideration, introducing some improvements represented in Fig. 75, which was exhibited in the Argentine Mining and Metallurgical Section at the Chicago Exhibition in 1893. The jury on scientific instruments gave the highest award for the instrument, finding the chief points of excellence in it to be as follows:

"1. It is an instrument of new appliances.

"2. Peculiarity, beauty and novelty of construction.

"3. Adapted to facilitate surveying operations with greater accuracy and in less time than is usual with surveying instruments.

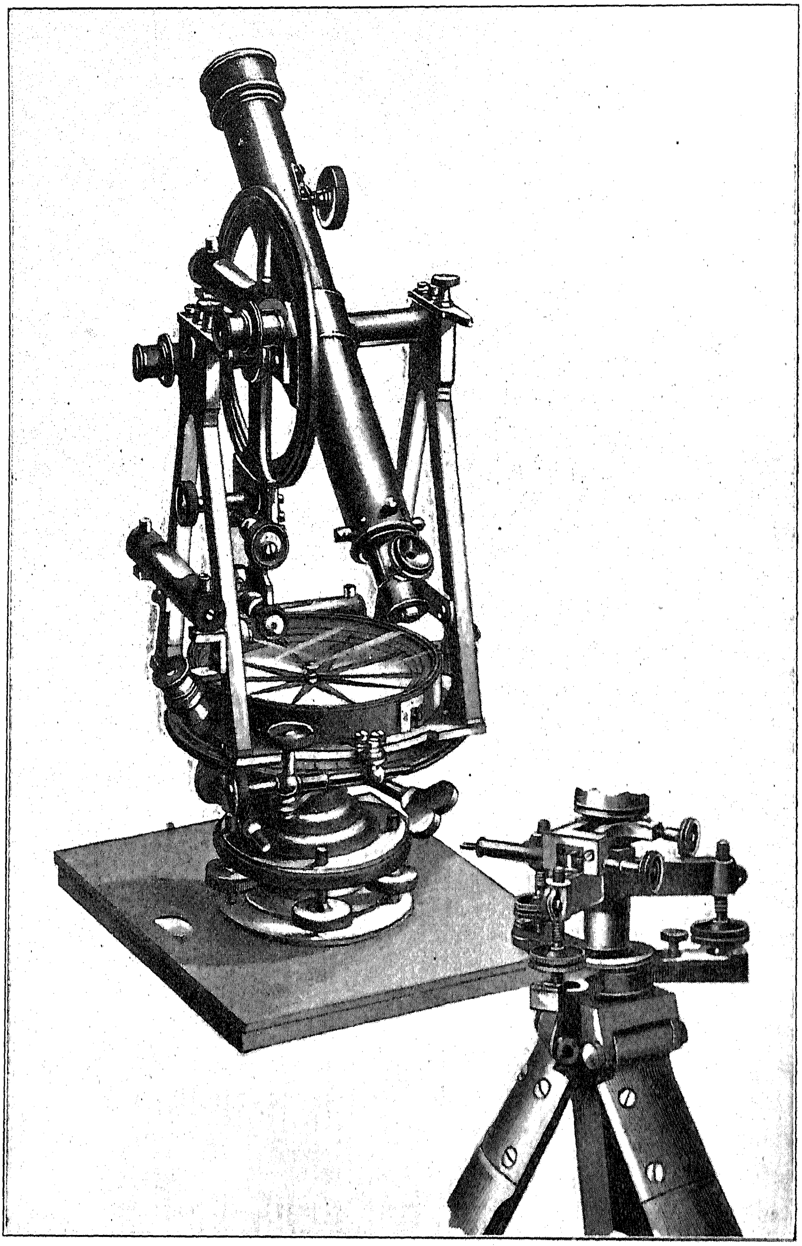
"4. It is a general labor and time saver."

As may be seen in Fig. 75, one of the principal improvements consists in the adaptation of a second, or, as we should term it, lower telescope, arranged to move upon a short horizontal axis, the telescope occupying an elongated or oval-shaped opening made in the center of the enlarged part of the lower vertical axis. Each end of the short horizontal axis is suspended in a collar between four adjusting screws, which pass through the termination of a short horizontal cylinder, the collar of which is firmly screwed or cast to the outside of the lower vertical

* *Trans. S. Wales Mining Engineers*, vol. iv., No. 5, 1865.

† *Trans. Am. Soc. Civ. E.*, vol. xxx., pp. 135–154, 1893.

FIG. 74.



HOSKOLD'S MINERS' TRANSIT THEODOLITE.

In the right-hand lower corner is shown the method of mounting upon three leveling-screws.

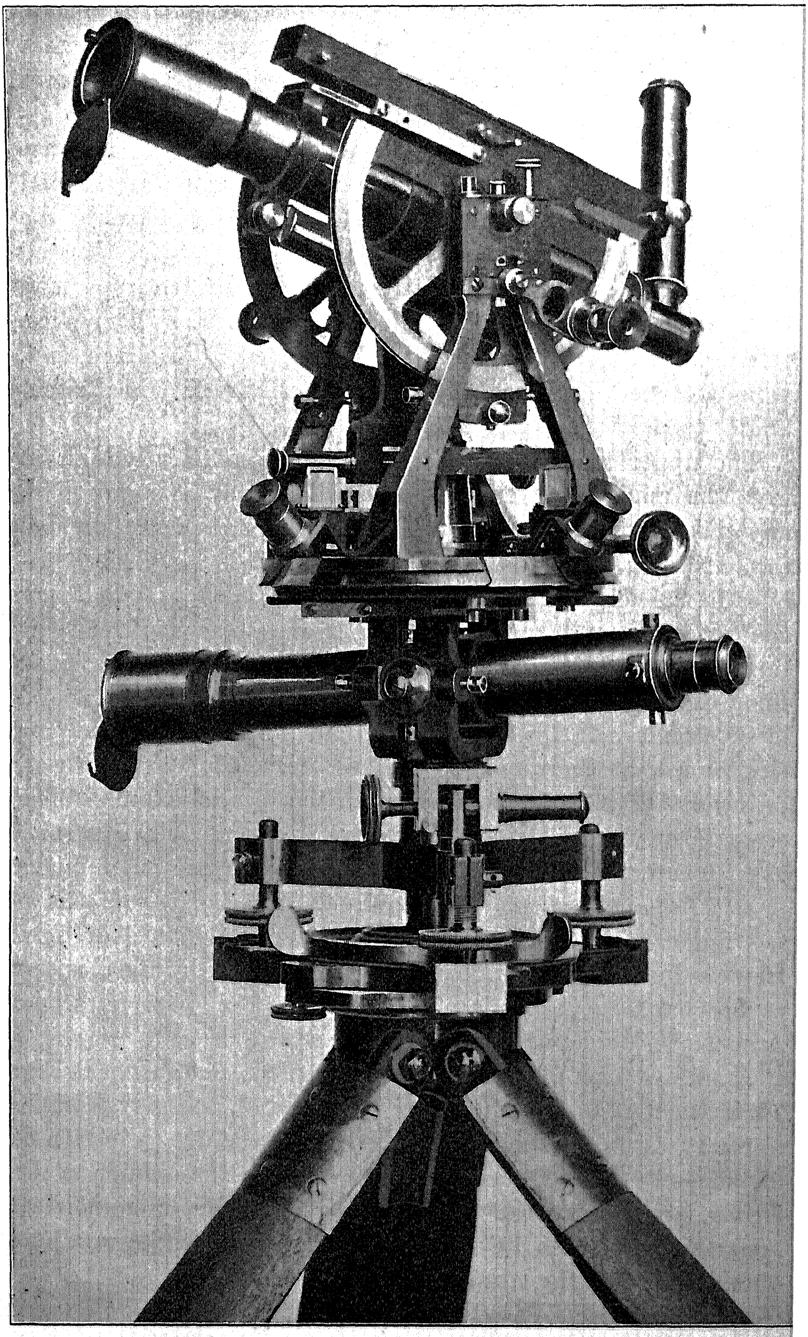
axis. The telescope is thus secured against lateral vibration, and, by the two sets of screws named, may be adjusted to coincide with the optical axis of the upper telescope when the zero of the verniers coincides with 360°, 90° and 180°. It moves vertically a few degrees, sufficient for sighting elevated or depressed objects within its range, upon the surface. For use underground, when elevated or depressed stations are beyond the vertical range of the telescope, a reflector applied to the object-end of the lower telescope reflects any object situated in the perpendicular or vertical; or the upper telescope may be used instead. By an ingenious contrivance of the maker, this reflector may be attached or detached at pleasure, and, when attached, its lateral plane or reflecting-surface is at right-angles to the optical axis of the telescope.

The upper telescope is mounted on Y's sufficiently high to give the amount of vertical angle which may be required in any class of mine; and its horizontal axis carries a divided semicircle on each side of the telescope, giving a perfect balance to the upper parts of the theodolite, without employing useless dead counterpoise weights. A groove about three-quarters of an inch in width and four inches in length is fixed upon the upper telescope, into which a corresponding part of a large circular, as also a long-trough, magnetic compass may be slid for use underground or upon the surface, independently of, or in connection with, the readings of the theodolite-limb. The circular compass carries a long sensitive needle with a vernier at each end, which may be made to read either to single minutes or to 20 seconds, as may be required. The horizontal axis of the upper telescope is perforated to admit the rays of light from a lantern to illuminate the hairs underground; or, for night-work, a reflector is also attached to the lower telescope. A sensitive stride, or axis-level, is provided also.

A special form of micrometrical eye-piece, not shown in Fig. 75, is attached to the telescope when required, and may be made to read to single seconds. Its chief use is the determination of distances by the sub-tense system,* which, in the opinion of the writer, is much superior to the stadia plan. This micrometrical apparatus may also be used as an auxiliary to the readings obtainable from the verniers of the theodolite.

* *Trans. Am. Soc. Civ. E.*, vol. xxx., pp. 147, 148.

FIG. 75.



HOSKOLD'S ENGINEERS' THEODOLITE

The simple but efficient arrangement of two telescopes in the instrument under notice enables an observer to dispense with the usual practice of making the zero of the verniers coincide with 360°, 180°, etc., or zero of the divided circle, every time any angle has to be measured in traverse or circuitous surveying, thus reducing the time and labor at least to one-half of that required by the use of other classes of surveying-instruments, and, at the same time, securing greater accuracy and certainty in the final results.

The *modus operandi* is simply to set the instrument over a station, properly level it, and direct the lower telescope upon the back-station, and the upper telescope upon the fore-station, neglecting the vernier readings during the operation; then a single reading determines the amount of the observed angle between the optical axes of the two telescopes, which is also that between the two stations. If the observer has not sufficient confidence in his manipulation, or suspects that some slight displacement of the instrument or slipping of the screws has occurred during the interval of the observation, he may decide the question instantaneously by applying the eye to each telescope in quick succession, when, if no error has been introduced, the vertical hairs of each telescope will continue to strike through each station-mark. If, on the contrary, any slipping of the parts of the instrument has resulted, it is instantly corrected by applying the eye first to the lower telescope, bisecting with the body tangent-screw, and then to the upper one, performing the same operation with the upper tangent-screw. Or, if the error was only due to an imperfect observation made with the upper telescope, the last operation will suffice for the correction. However, with proper care, no such vitiating error should occur.

It is apparent that with the use of a theodolite having only one telescope, no such instantaneous check-proof can be obtained at each station, at least without reversing the telescope from the fore- to the back-station, or *vice versa*, and then examining the vernier-zero in order to determine if it coincides with the zero of the divided circle as at first fixed. Each of the known modes of measuring horizontal angles in traverse or circuitous surveying requires two separate readings before an angle can be determined. This would be the case when the vernier-zero

is made to coincide with 360° at only the first angle, and when at each succeeding station each preceding angle or fore-reading is made to become the back-reading alternately. For the engineer is never certain that some slight displacement has not occurred during the transit from one station to another, due to jarring or the slipping of screws, verniers and divided circle, contraction or expansion of parts; or it may be that the operator has unconsciously touched the tangent-screw of the vernier and divided circle, etc., rendering a constant examination of the vernier-readings an absolute necessity for both back- and fore-readings, comparing them with the book-entries, all of which means a waste of time and extra mental and manual labor. To insure absolute freedom from error, when the vernier-zero is employed for all the back-observations, it is necessary to observe the supplementary angle, or, at least, repeat the angle, either of which would involve four separate operations and readings.

On the contrary, even when the supplementary angle is taken by the theodolite under consideration, Fig. 75, only two separate readings are required. For example, suppose that the angle is 178° 35′ 15″, and the supplementary equals 181° 24′ 45″, then 178° 35′ 15″ + 181° 24′ 45″ = 360°, as it ought to be if the instrument is in perfect adjustment and the manipulation is correct. Any difference from an entire circle would show the amount of error—plus or minus. A small amount of error, amounting to from 15″ to 20″, will sometimes exist, when instruments are inferior, and is difficult to eliminate. It will, therefore, be manifest that the lower telescope is capable of rendering incalculable service.

This instrument may also be made to take the place of a transit-theodolite for a variety of operations, especially in producing transit lines. For example, when it is necessary to produce any given line—a frequent operation in a certain class of surveys—it is done by first placing the telescopes to look in opposite directions, making the zeros of the three verniers of the horizontal circle coincide nicely. The lower telescope is then directed to the back-station; and the optical axis or vertical wire in the upper telescope points out the direction of the transit line. The verniers being double, there are nine distinct readings by which to effect the coincidence before producing the

line; and as the verniers read to fifteen seconds, the probable error, plus or minus, would be $\frac{15}{9} = 1.66$ seconds. It is doubtful whether a line could be prolonged by a transit-theodolite within this limit of error.

Where townships or extensive areas of land are required to be set out in blocks, this instrument would prove invaluable, for the reason that the two telescopes may be set at right-angles at the commencement of a day's work, and the corresponding work set out with the greatest facility and accuracy. It may, however, be convenient to examine the vernier-readings as the work proceeds.

In the wide arms carrying the reading-microscopes, and just behind each of them, a hole is drilled, and on the top of each hole a reflecting prism is screwed, having a horizontal motion, so that each of them may be turned until a ray of light is caught and reflected upon the verniers, which are thus effectually illuminated, so that it is not necessary to bring the light of a candle or lamp inconveniently near the head when the angles are read.

When the instrument is used on the surface, the long or trough magnetic compass is slipped into a corresponding groove to receive it under the horizontal divided circle, or on the top of the upper telescope.

By preference, a triangular leveling- and centering-frame of light weight, with three leveling-screws, is attached to the theodolite, Fig. 75. The conical heads of these screws are locked by a slipping plate into a similar triangular frame, which is screwed to the top of the tripod-stand. This leveling-frame carries two other thin movable plates, and vertical pins working in elongated slot-holes, and a circular clamping-ring. By means of this beautiful apparatus, invented by Troughton & Simms, the instrument has a free motion in all directions, carrying the plumb-line and bob with it, and can thus be easily and accurately centered over a fine mark made in the station.

Another theodolite of this class is now in course of construction by Troughton & Simms, and more closely corresponds to this description than the one represented by Fig. 75, which was hastily constructed to be exhibited at the Chicago Exhibition. It will have every modern improvement that the application of mathematical principles, mechanical art, and

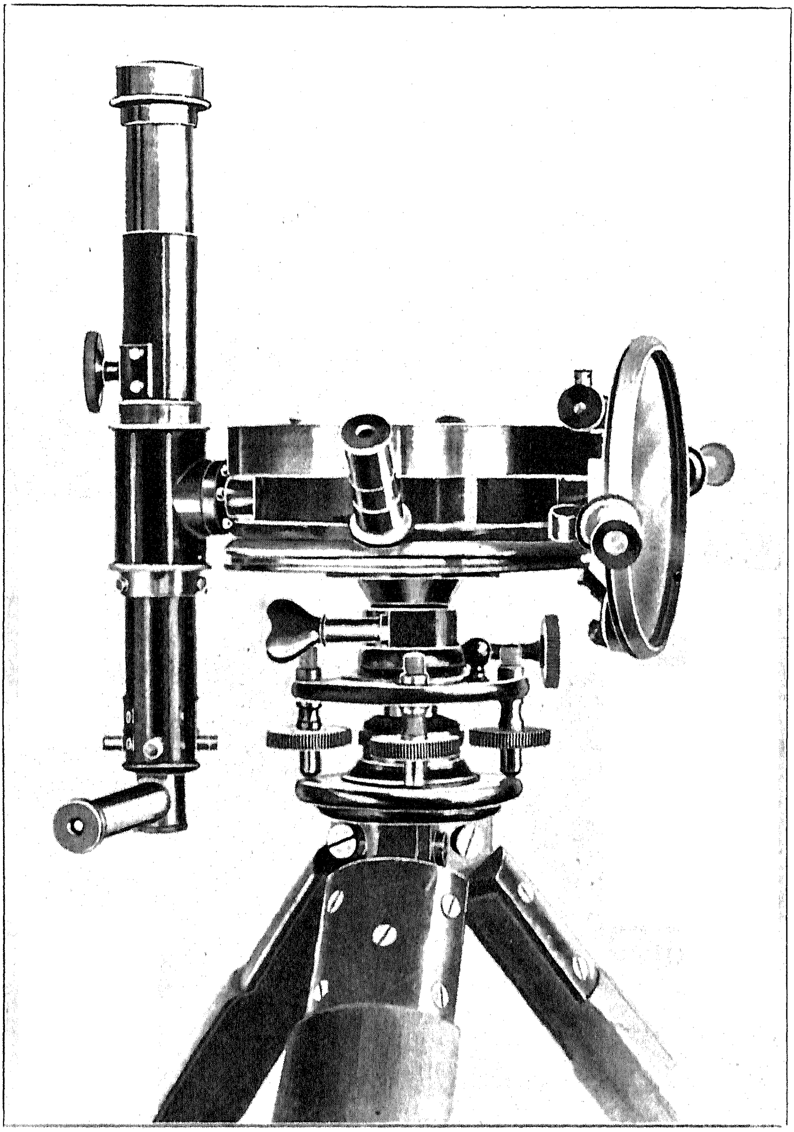
good workmanship can command, or exact surveying require. All the parts, except the bearings, axis and screws, etc., are made of composite aluminum metal; consequently, weight should not now be considered an objection to the general use of the theodolite for mine-surveying. Unfortunately, however, this kind of opposition to necessary progress will still continue in various quarters. It would be a false affectation of modesty not to note that American and other authorities have decided that this type of instrument is the best English theodolite yet introduced for general underground and surface-surveying.

On page 706 of Mr. Scott's paper reference is made to another quite distinct class of mine-surveying instruments, *i.e.*, the type known as theodolites with eccentric telescopes working round the circumference of the divided circle, instead of over its center. The French appreciated this plan, and it also prevails in Germany to a considerable extent. The great objection to French instruments of this class is the dead counterpoise-weights that they are obliged to apply at one side of the instrument, in order to balance the telescope, vertical circle and level placed on the opposite side. Combes introduced a similar and more portable instrument of this type for mine-surveying in 1845. Mr. Scott has represented it in Fig. 23 of his paper, as also the double target for sighting; but it is the opinion of the writer that this instrument was not much favored out of France. Casella also introduced in 1869, for the use of travelers, a very small instrument of this kind, superior in some respects, but inferior in others, to that of Combes. It is well balanced, but, in order to effect this, he has mounted a horizontal axis over and across the diameter of the magnetic compass, with a level on the top of the axis and at right-angles to it. This axis carries a telescope on one side and a vertical circle on the other. The obstruction due to the horizontal axis and level renders the instrument of no value as far as the magnetic compass is concerned.

The type represented by Fig. 76 in elevation and Fig. 77 in plan, and denominated *angleometer*, is of the same class as that of Combes and Casella, but superior in construction to either. It was designed by the writer some years prior to 1870, and consists of a divided horizontal circle, vernier-circle and double vertical axis, mounted upon a four-screw leveling-base, as is

common in theodolites. The horizontal axis carries a telescope at one side of the horizontal vernier-circle, and a vertical circle

FIG. 76.

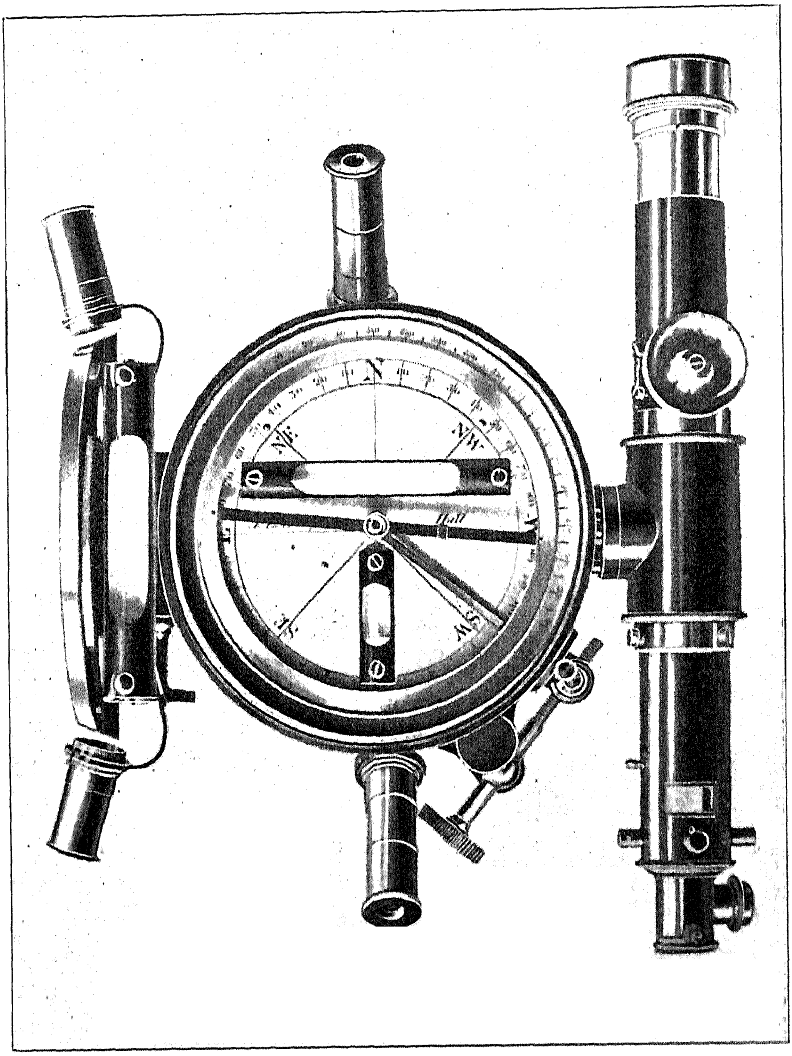


HOSKOLD'S ANGLEOMETER.

with sensitive level, attached to the verniers at the opposite side. The horizontal axis is mounted on very low bearings, a little higher than the diameter of the axis, and screwed to the upper

side of the vernier-circle. The magnetic compass is placed over the horizontal axis, and almost in contact with it; the outer ring or circular portion of the compass-box is continued

FIG. 77.

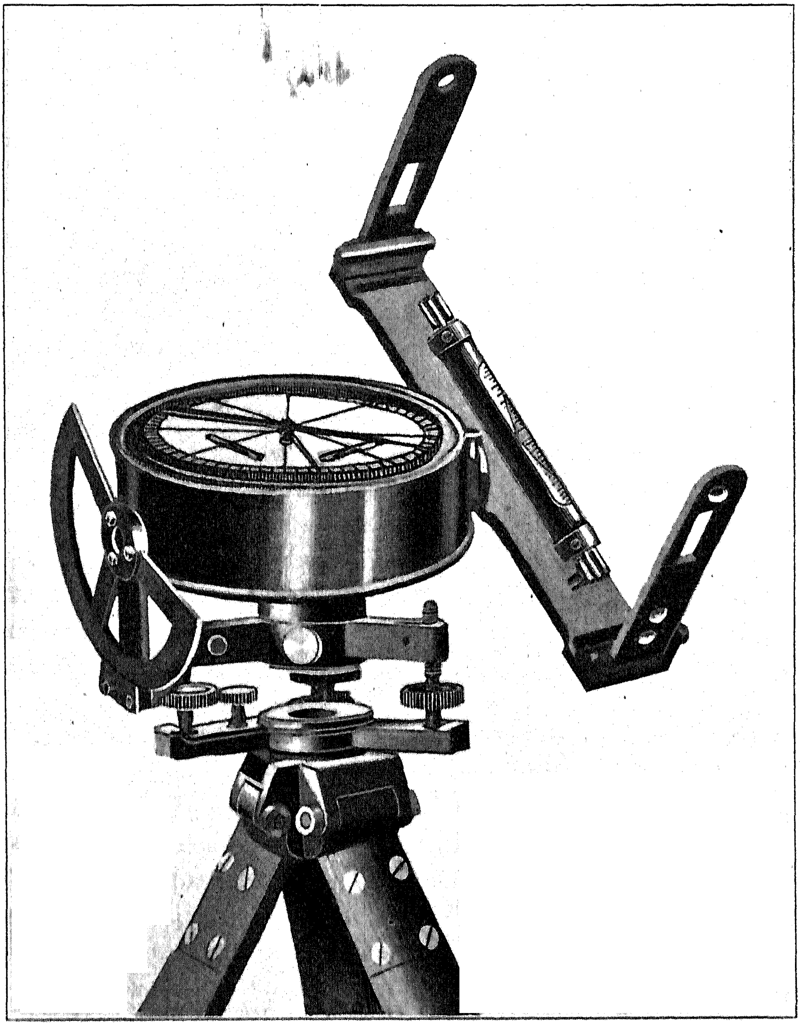


HOSKOLD'S ANGLEOMETER.

down to meet in contact with the vernier-circle or plate, so that the axis and its bearings are hidden from view. The magnetic needle carries a very light and delicate circle, as in a prismatic compass, with vernier-readings; but verniers reading to 20

seconds are preferable to the circle. The particular construction of this instrument insures a perfect balance of the parts, and leaves the face of the magnetic compass free for fine magnetic observations. This instrument is the most useful of its

FIG. 78.



HOSKOLD'S SURVEYING COMPASS.

type, especially in low and confined roads in mines, as also for connecting the first line in an underground survey to the surface by direct telescopic sight down a shaft. It is also well adapted for the observation of stars near the zenith for lati-

tude- and time-determinations. It was a patented instrument, and received the highest award in the Scientific Instrument Section of the London Exhibition in 1872.

A very plain and useful magnetic compass, Fig. 78, was also exhibited at the same time. It is similar in construction to the angleometer, without the theodolite divided circle. The horizontal axis works through the bottom of the compass-box, carrying plain sights and a sensitive spirit-level on one side and a semicircle with verniers and clamp tangent-screws on the other. The ordinary levels are placed in the compass-box. The instrument was afterwards altered by adding a level to the vernier-arm of the semicircle, and mounting it with three leveling-screws in the same manner as a theodolite.

The great objection urged against the use of the eccentric theodolite type is the error occasioned in the angles when a telescope works round the limb of a divided circle instead of from its center. Combes avoided this error by the use of his double target. The writer used for surface-work station-poles with double points, one of which marked the station-point while the other was sighted to. For underground work, a specially constructed lamp and apparatus was employed for sighting-purposes, the lamp being removed as far from the station-point as the distance from the center of the theodolite to that of the optical axis of the telescope. When the angleometer was used in connection with this contrivance, good results were obtained.

However, all such contrivances may be avoided by observing the horizontal angles between the stations in the same manner as when an ordinary theodolite is employed, with the telescope over the center, and by using a circular protractor, constructed with a radial bar carrying another bar at right angles, mounted with folding arms and pricker-points to move round the circumference of the circle, the distance from the center to a line passing through the pricker-points being equal, on the scale of the plotting, to that from the center of the angleometer to the optical axis of the telescope.

It would occupy too much space to attempt to describe the construction and merits or demerits of all the forms of instruments which have been proposed to be employed in mine-[illegible] from time to time, because they are as various as the

capricious and impracticable ideas of those who attempted to introduce them. Of the instruments represented by Mr. Scott's paper, pp. 713 to 739, Figs. 45 and 55 appear to the writer to be the least cumbrous and most useful. At the same time we must agree that Figs. 56 and 57 possess the merit of substantial construction, and doubtless will supersede many of those previously in use in North America. The form exhibited in Fig. 57 appears to be preferable, for the reason that the writer has been unable to satisfy himself that the second telescope attached to Fig. 56 is absolutely free from lateral vibration. This, however, is a point which Mr. Scott may be able to clear up. One of the principal features in most North American surveying-instruments is the addition of a second or auxiliary telescope in one form or another, intended for the purpose of making a connection of underground workings, one with another, by sighting down steep inclines to the perpendicular, and also with the surface by sighting down a shaft; but some of the modes of attachment of the auxiliary telescope are exceedingly unsightly, cumbrously heavy, and are also uncertain in action.

So far as the writer knows, the first recorded attempt, in England, to perform the very important operation of producing a surface-line in any given direction underground by sighting down a shaft is to be found in a book by C. Bourns, now very scarce.* It was performed when the Box Tunnel was constructed by the Great Western Railway Company, England. Bourns says:

"The shafts were so deep (some of them from 300 to 400 feet), that it was found the plumb-lines would not answer the purpose on account of oscillations caused by currents of air or otherwise; the following method was therefore resorted to, viz., shafts 20 feet in diameter were sunk, in the line; the center-line at these shafts was fixed by a theodolite, or a transit-instrument, as the case might be. The mode of accomplishing this will be understood on reference to the figure [Fig. 79].† The instrument being first set in the line, on the surface, at A or B, and a point fixed in the bottom of the tunnel by means of the vertical arc; and then another point found in a similar manner from the other side; a short length of line was thus obtained, which was carefully produced both ways to meet other portions worked from the adjacent shafts. These points, and the line through them, were tested at every length, before the brick-work was put in.

* *The Principles and Practice of Engineering and Other Surveying*, C. Bourns, 3d edition, pp. 249, 250, London, 1843.

† Copied from the original.

When a shaft is so deep that the range of the arc of a theodolite is insufficient to enable an observer to see to the bottom of a tunnel, a transit-instrument must be made use of instead."

Such is the description given by Bourns in the work previously referred to. It is highly probable that the transit-instrument to which he refers was similar to, or at least some slight modification of, Fig. 80, which is copied from F. W. Simms's* figure of an instrument made by Troughton.

The portable meridian transit named had a telescope 20 inches in length, with a diagonal eye-piece for observation in

FIG. 79.

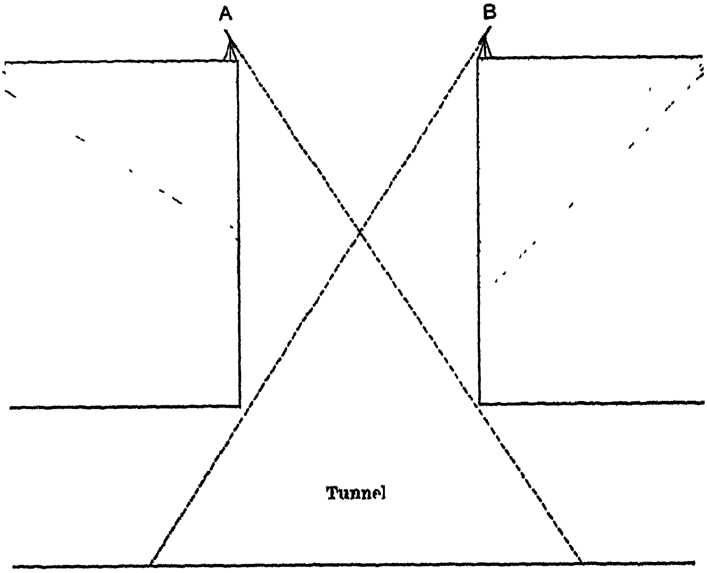


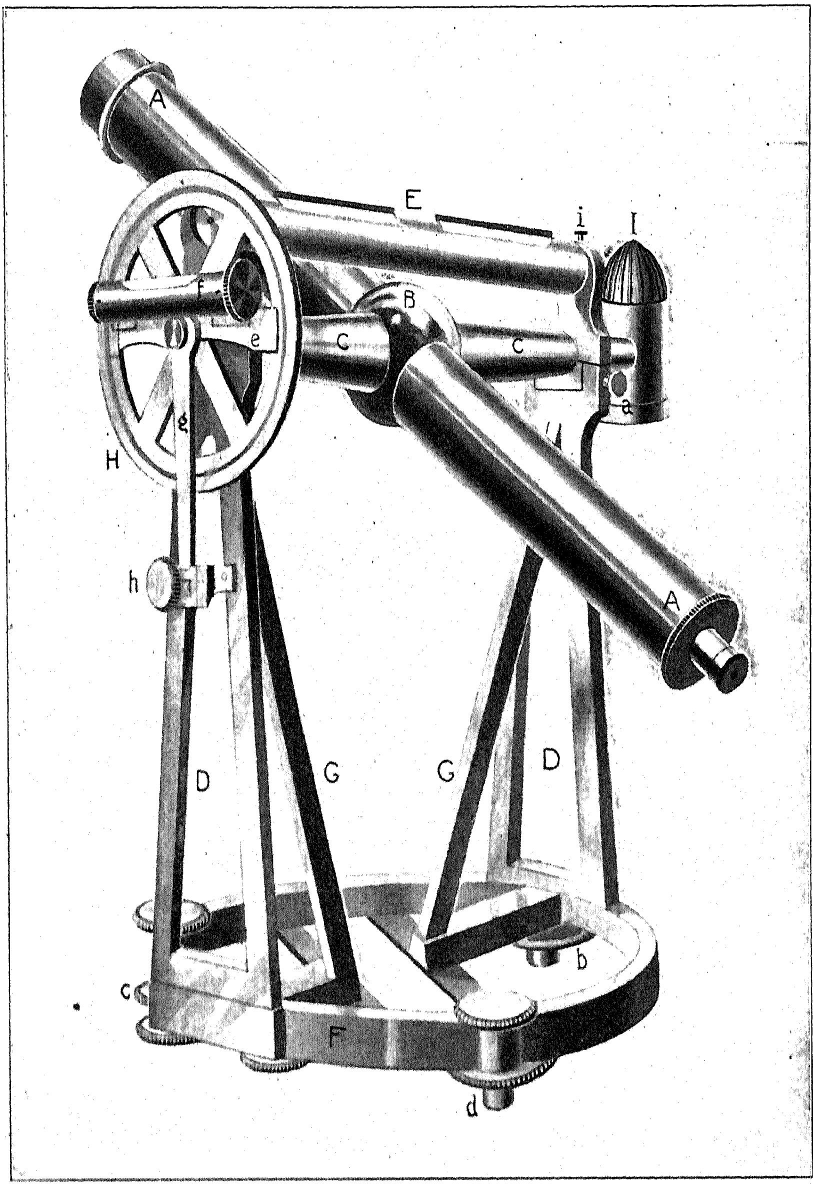
DIAGRAM ILLUSTRATING BOURNS'S METHOD.

the zenith and nadir. The circular ring base, upon which the upper parts of the instrument rested, offered great facilities for nadir-observations. However, considerable time was expended in bringing the optical axis of the telescope to the vertical plane of the line, which had to be produced down a shaft into a tunnel. The heavy and massive base now attached to this class of instrument renders it of less service for nadir-observations than the old pattern.

Mr. Beanlands, however, perfected the system of connecting

* *A Treatise on the Principal Mathematical Instruments Employed in Surveying, Levelling and Astronomy*, F. W. Simms, Ass't at the R. Observatory, Greenwich, p. 62, 1836.

FIG. 80.



PORTABLE TRANSIT INSTRUMENT
TROUGHTON

surface-lines with underground workings, and *vice versa*, and applied it to mine-surveying in 1856 with great success.*

* *Trans. North of England Inst. Mining Engineers*, vol. iv., pp. 267-273, 1856.

Many years since, when the writer occupied himself largely in mine surveying with various kinds of instruments, the telescope of his angleometer was employed to fix a short base-line in shafts not more than 10 feet in diameter. The two points thus set out were used to drive a short piece of tunnel to a point where the longer portion of the tunnel took a different direction. The third point or station at the bend in the tunnel was determined by stretching a fine copper wire through the two points previously determined at the bottom of the shaft, and from this third station the principal part of the tunnel was set out, the direction of which depended upon a long survey made at different levels. One of the tunnels referred to was over 300 yards in length, and when the workings met from the two sides no appreciable difference could be detected in the axial direction or in the levels. When a survey is conducted with the necessary instruments and amount of care, and the system of co-ordinate calculation and plotting is adopted, and the base of the survey is no longer than that indicated, the same amount of precision should result, though the tunnel were ten times as long.

Similar operations, on a larger scale, were carried out in driving a railway-tunnel, three miles in length and from opposite points, under the river Severn, in England. When the meeting-points were gained, the axial line of the tunnel was perfect. In this case a powerful transit-instrument similar to Fig. 80 was employed to fix the two points of the base-line transferred from the surface to the bottom of the shafts.

Various other cases might be cited to prove the efficiency of this plan of making connections, which, thanks to Bourns and Beanlands, will never be superseded by any other method. The only difficulty is to procure a sufficiently portable instrument capable of performing this operation, as well as all others which may be required in general surveying.

The old cradle-type of theodolite, Fig. 17 in Mr. Scott's paper, has a very substantial construction, and, as now made, is capable of performing excellent results, and possesses the advantage of resisting a good deal of rough work before becoming impaired. If an extra pair of Y's, longer than those at present employed, were made to attach and detach at pleasure, the telescope could be thrown forward sufficiently to enable an observer to

sight down a shaft. When a young man, the writer did excellent work with this class of instrument, which was then thought to be a grand acquisition. For general underground work a 5-in. magnetic compass was specially made to attach and detach, by means of screws, at the top of the telescope of this type of theodolite; and by this mode many curious and erratic differences were discovered in the direction of the lines as determined by the theodolite-limb and the magnetic needle. The magnetic needle was read by means of a strong microscope, all objects of iron or steel being removed to a distance during the time occupied in the magnetic observations.

The difficulty experienced by Mr. Scott and others in reading theodolites more finely divided than to single minutes is principally due to the result of the divisions being placed on the flat or horizontal upper face of the circle instead of upon a conical or beveled-edge form, as is generally adopted in England, where the divisions upon flat circles have been abandoned for many years past.

The writer does not agree with Mr. Scott in the opinion that "the novice is generally too much inclined to high telescopic power and fine graduations, with the idea that greater accuracy can thus be attained," etc. It is evident that if Mr. Scott could be certain of reading the observed angle in all cases to a minute of arc precisely, and could be positive that nothing remained which could be determined by a more finely-divided vernier, then his assertion might hold good, and could be boldly urged; but considering that frequently it is difficult to determine with absolute precision which of any three minute-divisions, close to one another, is the one most nearly in coincidence with a division upon the divided circle, it is manifest that, in the majority of cases, there must exist a small angular quantity which a vernier divided to read to a single minute of arc will not indicate, and which must remain undetermined. This small angular quantity will fall between one and fifty-nine seconds in the minute-division preceding or succeeding to that supposed to coincide with a division on the divided circle. This error or discrepancy in one course of a traverse survey swings the whole subsequent portion of the survey round by an equal angular amount; and consequently results in a more prominent error in long surveys than in short ones.

To illustrate this principle: Supposing that the observed angle is 164° 31′ 0″, and the supplementary angle 195° 28′ 0″, then 164° 31′ + 195° 28′ equals 359° 59′ 0″, or one minute in defect; but this difference of one minute would not have been known without taking the supplementary angle. On the contrary, employing a 20-second vernier, we find the first angle to be 164° 31′ 40″, and the supplementary angle, 195° 28′ 0″; and 164° 31′ 40″ + 195° 28′ = 359° 59′ 40″, which is only 20 seconds from the truth, showing clearly that this class of vernier-theodolite is at least twice as accurate as that with a minute-vernier. Naturally a 15-second vernier would give closer results. For example, let the first angle observed be 164° 31′ 40″, and the supplementary angle to be 195° 28′ 15″, then 164° 31′ 40″ + 195° 25′ 15″ = 359° 59′ 55″, or only 5 seconds from forming an entire circle. The use of a minute-vernier could not give such a close approximation to the truth. We find that in all high-class surveying the most accurately divided instruments, with fine readings and corresponding optical power, are adopted. We cannot afford to become inattentive to well-established principles and practice, nor can it be permitted to descend in the scale of progression and agree that a five- or ten-minute vernier is as good as one divided to single minutes; for in that case we should go on degenerating until we accepted Ribero's division to a single degree, or Digges's to a two-degree division.

It is true, there is a medium course, and an instrument adapted to one class of work may not be the best for a different class of work. It is necessary, therefore, to determine the fineness of the divisions of a theodolite-circle and vernier according to the nature of the work and the degree of accuracy sought to be attained. An error of one minute would be serious on very long lines, if any important work depended upon the survey, such, for example, as a long tunnel driven from opposite ends, or the fixing of boundary-lines at a remote point between two or more rich mines; especially if the region to be surveyed were not an open one, free from such obstacles as would prevent checking by trigonometrical observations. During more than half a century of experience with various kinds of instruments, the writer has never experienced inconvenience in reading theodolites of 4 in. in diameter, divided to

read to 20 seconds of arc, and to-day he finds no difficulty in reading a 5-second vernier attached to a transit-theodolite of 8 in. diameter, which he sometimes employs for simple trigonometrical and astronomical observations. However, a good deal depends upon habit. The best-sized theodolite for general underground and surface work is from 5½ to 6 in. in diameter, reading to either 15 or 20 seconds, and this gives ample space between the divisions for facile reading with strong microscopes. Such surveying-instruments are now preferred in nearly all parts of the world. To avoid scratching, as far as is possible, the best metal to divide upon is platinum, and with gold verniers a more facile means of reading is afforded.

Mr. Scott passes lightly over the sub-tense system of determining distances, probably for the reason that his single-minute theodolite would not command the process. Nevertheless, in the opinion of the writer, as previously observed, this is a most accurate and facile system, as has been proved on the great Indian surveys. The writer has pointed out what kind of apparatus is required in connection with a theodolite for performing it. The micrometer-microscope attached to the eye-piece of the theodolite of the writer, now in construction and similar to Fig. 75, is all that is necessary. Such a simple auxiliary may be applied to any theodolite, and may be constructed to measure to one second of arc or less.

If it is required to measure, by the instrument shown in Fig. 75, an angle smaller than 15 seconds, the micrometer attached to the eye-end of the telescope is employed in the following manner: Suppose that the vertical hair intersects a station-mark, and the reading is believed to vary, plus or minus, from exactly 15, 30 or 45 seconds. The vernier-circle is turned backwards until the verniers mark the nearest of these numbers. The vertical hair should then appear out of contact with the station-mark; and the small distance from the permanent vertical hair in the telescope to the station-mark is measured with the micrometer. Let this measure be 11.6 seconds, and the previously measured angle 174° 10′ 30″, then the entire angle would be 174° 10′ 41″.6. For instruments of small size this is a more convenient plan than that of attaching long and powerful micrometrical microscopes to read the horizontal circle instead of verniers; because such an arrangement renders

the instrument more costly, cumbrous, bulky, and liable to get out of order.

The following is an example of the Tanner mode of determining distances:

Measured angle, 3° 10′ 31″.4; sub-tense base, 30 meters.

Then *log.* of the base of 30 meters, ...	1.4771213
And *log. co-secant* of 3° 10′ 31″.4, ...	11.2565632
Log. of the distance required, ...	2.7336845
Distance required, ...	541.60725

The average of several measurements of the angle should be employed. When the distant point is in an elevated place, the length of the line to be determined would be that of the hypothenuse of a vertical right-angled triangle, and should be reduced to the horizontal by the ordinary rule.

Cook & Sons, of York, introduced some years since a new model of surveying-instrument of the transit-type, the standards or Y's of which, and the vernier circle, are cast in a single piece, insuring great stability and freedom from vibration. The lower circle has a square outer edge, similar to a thin cylinder, and the divisions are marked upon the upper portion of the square edge, so that the vernier, being also square-edged, fits so nicely that the division line between vernier and circle is almost imperceptible. The vertical circle is divided in a similar form. The divisions are read either by direct sight through horizontal microscopes or by perpendicular sight through prismatic microscopes. The instrument of this class, formerly used by the writer, had very low Y's, without transit-movement, and was found to be a very efficient instrument.

The writer cannot agree with Mr. Scott's opinion upon Everest's theodolite, which is a very elegant, useful and light instrument. No one knew better than Everest what was required for filling-in surveys in a hot climate like that of India. The instrument is constructed to-day with divisions upon a beveled-edge circle, and has other improvements; and when the country to be surveyed is not very mountainous, as in England and in a large part of the Argentine Republic and other surrounding republics, this instrument is, and could be further, used with great advantage, especially when the lines are long and

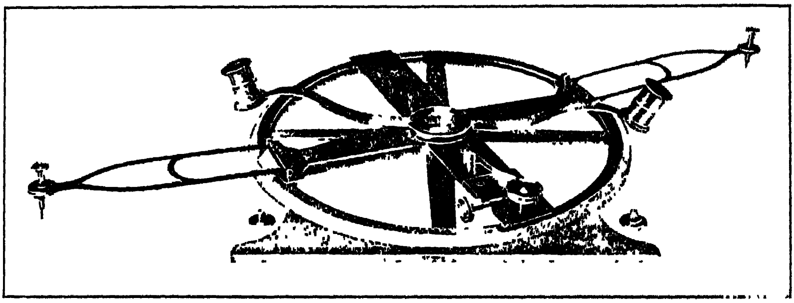
the engineer becomes fatigued from excessive heat in passing from station to station. Under such circumstances, any one would endeavor to avoid the extra weight unavoidable in heavy transit-theodolites. However, circumstances must decide what instrument is best adapted to a certain place and class of work.

As all practical engineers know, all underground surveys should, if possible, be conducted in a circuitous traverse form, always seeking to finish at the point of commencement; the corrections of all the angles may then be determined before leaving the mine, or at least before plotting the work. The sum of the internal angles, treated by the well-known rule, will exhibit any error which may exist, plus or minus. If none such can be found, and the plotting will not agree, then the error must be sought for in the measure of the lines and not in the angles. Long before 1863, the writer advocated that the first underground line—continued—should be made a common base to which all the underground and surface-surveys should be referred; that is to say, this line should be laid down as a common meridian prolonged throughout the plan, from which line all the angles observed underground and on the surface should be plotted. In that year he published this system, demonstrating its great utility and superiority, and showing that no accumulation of error could exist, as is too frequently the case when the co-ordinate system of plotting is not adopted. This plan only requires that all the observed horizontal angles should be reduced in such a manner that they are in a proper condition to be set off or plotted from this first line, assumed as a common meridian for the whole. Moreover, as this is the line which should be produced upon the surface by the process already noted, it is the fittest to be selected for this object. However, with proper care the same reduced horizontal angles referred to may be plotted from this base-line by a single setting of a circular protractor and similar good results obtained. All that is required, in addition, is a long and accurately-made metal parallel ruler of sufficient weight to run parallel upon a board 20 feet long, without deviation, to transport the angles to the plotting-points or artificial stations on the paper.

A protractor similar to Fig. 81, which was constructed for the writer many years since by Messrs. Troughton & Simms, is well

adapted for this class of work. It is 10 inches in diameter, divided upon a silver beveled edge, and reads by two verniers to ten seconds. The folding arms are mounted at each end by a screw carrying fine pencil-points for marking off angles, instead of using steel points. The readings of the circle are aided by two strong microscopes, revolving in arms round the circle. When the protractor is fixed, it is kept in position by very fine needle-points screwed into the sides of the instrument and taking hold of the paper; or two weights may be applied. The beveled edge of the circle offers greater facility in reading than when the divisions are placed upon a horizontal or flat surface. There is also cast at one side of the circle a bracketed projecting piece of brass with a beveled edge forming a line a little longer than the diameter of the circle, and set parallel to

FIG. 81.



HOSKOLD'S CIRCULAR PROTRACTOR.

a line passing through the 360° and 180° divisions. This useful appendage enables the draughtsman to slide the instrument along a steel straight-edge, previously placed against the meridian line, with the view of plotting some of the angles from more than one position or station, when they are very numerous, and the pencil-dots representing them come too close together. The instrument has a clamp and tangent-screws, with a spring attached.

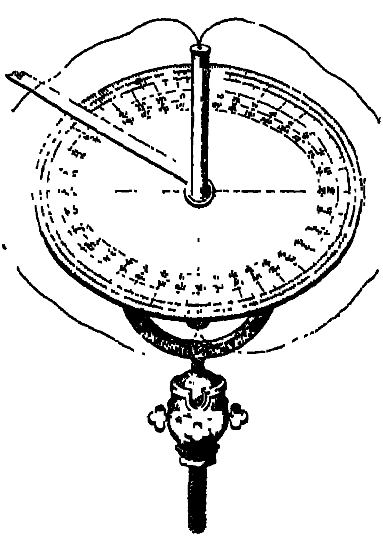
If either of the modes of working indicated in the foregoing remarks were always employed, using the theodolite to observe the angles, independent of magnetic bearings, no need could exist for the true or magnetic meridian; but as some people will always have a fancy for the use of the magnetic compass, its corresponding meridian, as also the true meridian, may be

determined and laid down upon mining plans, at least as an ornament, and to satisfy curiosity or other exigencies.

The writer desires that this contribution shall be taken as an independent paper upon mine-surveying and instruments, as well as representing his part of the discussion of Mr. Scott's paper, which, in his opinion, is a very creditable, useful and important production.

MR. SCOTT: I think that I shall voice the sentiments of the Institute at large when I take this occasion to thank Gen. Hoskold for his very elaborate and scholarly contribution to the topic I was trying to cover in a few pages. His description of the old manner of conducting underground surveys by the graphic method of snapping chalk-lines on the top of a 3-legged stool is very interesting. No doubt this was the practice, as he explains, before Houghton wrote his fifty-nine articles on the "Laws and Customs of the Wapentake Lead-Mines;" but is it not more reasonable to suppose that it found its rise in the systems of plane-table surveying that were in vogue nearly a hundred years before?

FIG. 82.



Voigtel's Mining Astrolabe.

I am of the firm belief that the science of mine-surveying in all its forms, as well as all the instruments devised to facilitate the art, were in nearly every case derived from some method previously pursued in field, geodetic or astronomical surveying. Thus, as he has recorded here, the astrolabes exhibited by the British Museum date back to the 11th century; while the oldest instrument of this class that I know of as being employed in mine-surveying is one described by Voigtel in the first edition of his work (1686) as something new—of such recent manufacture, in fact, that he was unable to include it in its proper place in the 14th chapter of the work, which treats of the use

of two or more *Scheiben* in conducting surveys in iron-mines. Voigtel says:

> "It is a newly invented instrument, by use of which the operations in iron-mines are conducted still more accurately than by any of the methods previously described. It is divided into 360 degrees. Through its center is a hollow tube, as high as the diameter of the plate, extending, one-half above and one-half below, at right-angles to the plate, tapering somewhat toward its extremities. Through the tube two waxed threads are drawn and tied at the ends, one set extending forward, the other backward; and into these loops the measuring-cord or chain is hooked when at work. About the tube revolves an index-arm, extending somewhat beyond the plate, so that when the cords are pulled taut in operation, it can reach them, and the horizontal angle can be read as indicated, even if the courses are elevated or depressed as much as 45°. Then there is a base with a wooden screw, so that the instrument can be set up on any timbering in which an auger has previously bored a hole. The base has a movable ball-and-socket joint with four screws (as shown in Fig. 83), so that the instrument can be properly secured for horizontality by means of a bubble-tube—too well known to require special illustration or description."

Mr. Hoskold's verifying or lower telescope, set so as to be always coincident with the zero of the vernier, is apparently a very ingenious contrivance, and of great convenience in taking back-sights; but why does he not adopt Mr. Wagoner's cyclotomic circles with it, so that the azimuth axis (which must now of necessity be inverted between the standards) may be dispensed with, thereby making his theodolite a *transit* instrument? While the matter is now before us I would advance the proposition that this cyclotomic principle is the only correct one yet devised for nadir-instruments in which the vernier-circles are to be preserved; for the perforation in the simple vertical axis may be large enough for all practical purposes without perceptibly increasing the size of the base. The A. Lietz Co., 422 Sacramento Street, San Francisco, Cal., will be glad to furnish full information concerning the means whereby a repetition-theodolite may be constructed upon a single axis of revolution.

I cannot permit myself to enter into a prolonged discussion upon the relative merits for mining work of minute-graduations as compared with those of finer divisions. On this point nearly every engineer has an individual opinion very difficult to influence one way or the other. The reason I advocate minute-graduations is because the possible error of the angular measurements is substantially as small as that of the linear ones.

A 100-foot steel tape divided into 10ths and 100ths of a foot is, I believe, most generally used by American engineers for the measurement of underground courses. In a 5-inch circle, graduated to read minutes, the maximum error will probably not exceed 30 sec., whose corresponding lineal error in an average course of from 50 to 100 feet can scarcely be detected on a tape of the above description. Many American engineers have been, and, I believe, are still using a chain underground;* but there is no sense in too highly refining the instrument while the means of measurement are in so many cases quite rude.

It seems strange that Mr. Hoskold should declare himself favorably inclined toward Figs. 45 and 55, and object to my interchangeable auxiliary, when placed on top of the main telescope under conditions almost identical with the others mentioned. There is no form of detachable top-telescope conceivable to me in which the possibilities of lateral vibration are so completely removed. The vertical pillar, to which the auxiliary is firmly screwed and clamped, is cast in one piece with the telescope-hub, just as are the horizontal axes, and there is no more possibility of vibration in one than in the other. Figs. 45 and 55 are, as I have said, in my opinion, excellent types; but neither, I believe, is so simple in construction, nor can either be used at the side if occasion should require it. There is no room, certainly, for a distinction between Figs. 56 and 57; for they are the same instrument, and the construction and method of application, as well as the means of adjustment, are precisely similar.

As to Everest's theodolite, all I have said about it is on p. 697 of my paper, and amounts to nothing more than a simple statement that the instrument "practically became obsolete twenty years ago." Beyond what this statement might be deemed to imply, I expressed no "opinion" whatever.

JAS. B. COOPER† (communication to the author): If Mr. Hoskold is correct in saying that the first instruments used for surveying consisted of two movable cross-bars of wood or

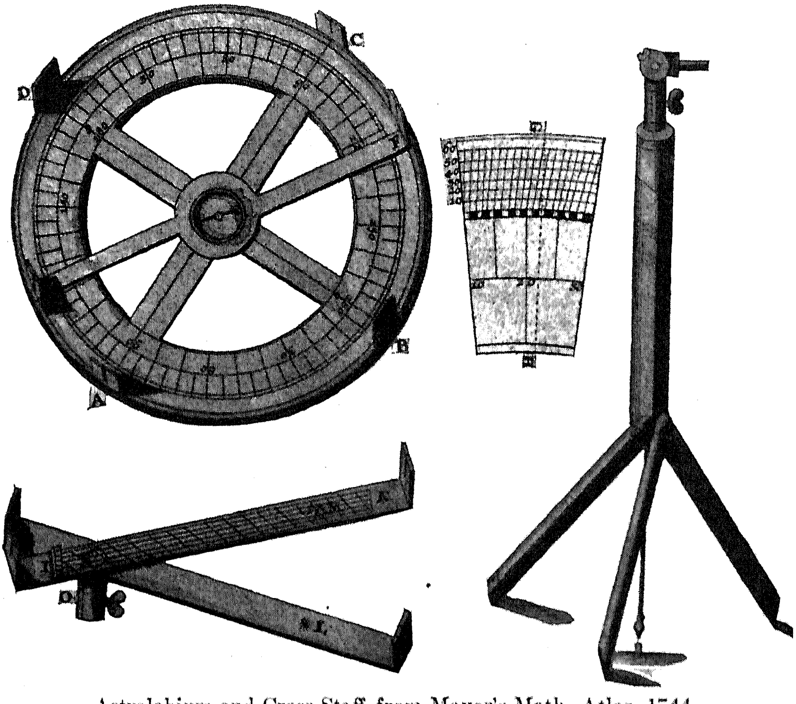
* *Report on Mining Methods, etc., in the Anthracite Coal-Fields*, H. M. Chance, Harrisburg, Pa., 1883, p. 371.

† Supt. Calumet and Hecla Smelting-Works, South Lake Linden, Mich.

metal, fixed to the top of a rod, then we have here in Fig. 83 a survival of the most ancient method ever used.

All the figures given in this cut (though rearranged to suit the present need) are taken from Tab. XI. of the *Mathematischer Atlas* by Tobias Mayer, Philomath, Augsburg, 1744. The lower figure represents the cross-staff as described by him. It consisted of two plain brass rules pivoted upon each other

Fig. 83.



Astrolabium and Cross-Staff from Mayer's Math. Atlas, 1744.

near one end, as shown, and provided with simple sights at each extremity. From the center, N, were marked off very accurately the points M and L, so that they should be equidistant from the center. In whatever relative position, then, the rules might be placed, N M and N L would always be equal and mark the sides of an isosceles triangle whose base, L M, would naturally vary in proportion to the size of the angle measured through the sights. When the sights had been fixed very carefully on their respective objects, a pair of compasses was employed to measure the distance L M, which was at once

determined in terms corresponding to the other sides upon the scale I K, after which the angle M N L was calculated.

This instrument was mounted upon the tripod shown, the construction of which, as Mayer says, is too well known to demand special description.

This tripod was likewise used with the *Astrolabium*, which he also introduces, and was so constructed that the spindle at the head could be tipped to a horizontal position for the measurement of vertical angles. He says:

> "For the measurement of angles in the field and for the laying out of the same we use the astrolabium. It is usually made of brass, though sometimes also of wood, and has a diameter of from 8 to 12 inches, divided into 360 deg., and by use of the diagonal scale, G, to 10 or even 5 min. of arc. At each quadrant are placed the diopters A, B, C, and D, and from the center revolves the rule E F, at the ends of which are also placed two diopters somewhat higher than the others. The observations are read to 10 minutes of arc, with the 20° diagonal scale; by which it will appear that the line G H, for instance, marks the angular value of 22° 20′."

This is a method of reading angles not mentioned by Mr. Scott; but I am undecided as to whether it has an individuality all its own, or is only a modification of the *nonius* he has described on pp. 737, 738.*

W. S. Hungerford, Jersey City, N. J. (communication to the Secretary): In connection with the very able and complete paper of Mr. Scott on "The Evolution of Mine-Surveying Instruments," a short description of the instruments and method employed by the writer, some fifteen years ago, at the iron-mines of Low Moor, Va., of which he was superintendent, may be of interest.

In the mines referred to there were several main track-levels approximately parallel and about 100 feet apart vertically, and at varying horizontal distances, according to the dip of the vein, which was from 50° to 75°. Between these levels there

* Secretary's Note.—The diagonal scale (or method of transversals, as it is sometimes called), is said by Thos. Digges (*Alæ seu Scalæ Mathematicæ*, *Capitulum Nonum*, *Londini*, 1578), to have been invented by Richard Chanzler, an English artist famous for his skill in the construction of mathematical instruments, and to have been long well known in England. See Robert Grant's *History of Physical Astronomy*, London, 1852, p. 442. For these facts I am indebted to Mr. B. S. Lyman, of Philadelphia, Pa.—R. W. R.

were frequent upraises, and these again connected by frequent levels and workings of great irregularity and often difficult of access, but all of which it was desirable to keep promptly surveyed and plotted. The entrances of the main track-levels were either on the open side-hill or connected by a vertical hoisting-shaft. The main levels were all connected carefully with a transit-and-level survey with frequent permanent marks; these levels, ending at the hoisting-shaft, being oriented by means of two plumb-wires, as described in Borchers's *Markscheidekunst*, p. 143. The accuracy of this orienting was tested upon the opening of the first upraise to the next higher level and found, in a traverse of about a mile, to close within 4 inches. The transit surveys were carefully calculated by latitudes and departures, referred to an astronomically determined meridian, and plotted in three . . . . . .

The transit used was an 11-cm. instrument made by Aug. Lingke, of Freiberg, Germany, in 1877. The horizontal circle was graduated from 0° to 360° and read by two verniers to single minutes, as was also the vertical circle. A fixed reading-glass and a reflector were used for each vernier. With properly adjusted reflectors there should be no difficulty in getting the light on the verniers without burning the face. The vernier-readings could easily be estimated to 30 seconds, and by repeating the angles and taking the mean readings an accuracy of 15 seconds was attainable. By using rather high standards an angle of depression of 52° was secured; but beyond this no provision was made for observing very steep angles. The transit had no magnetic needle, and the telescope was inverting. The writer would add his endorsement to all that Mr. Scott has said in favor of this form of telescope. The usual objection that the inverting of the object is likely to cause confusion is, in the experience of the writer, entirely unfounded.

The intermediate upraises, levels and workings were surveyed by means of the cord, steel tape, hanging-compass and clinometer, of course using every available opportunity to check the work by connecting to the more accurately determined points of the transit-survey. The inclined distances were reduced to the horizontal and vertical by means of the trigonometer and the hanging-compass. The compass was designed to stride the transit at pleasure, as also to be used

interchangeably in a brass protractor-plate for plotting, care being taken that the drawing-table, stands, etc., contained no iron nails, screws or bolts. There was no local magnetic attraction in the mines; but in a few instances, where rails or other iron material influenced the needle, perfectly satisfactory results could be obtained by a slight variation of the method and by taking the magnetic bearing at each end of the cord. This method was found abundantly accurate for filling in between the transit-surveys; it was expeditious and entirely mechanical, and could be used in places where a transit could hardly be taken. In fact the assistant, a bright young man taken from the mining force, was soon able to make and plot these compass-surveys, and give the necessary directions for upraises, etc., without any aid from the writer. If it was desired to connect a point in one level with a point in another level by an upraise, the magnetic bearing between the two points could be taken directly from the horizontal projection, and from the known horizontal and vertical distances the angle of inclination of the upraise could be drawn on paper, and a triangular piece of board could be cut to correspond and given to the mine-foreman, who had only to keep one side level, and the other on a straight edge, to get the required inclination.

In this connection a simple device of the writer for controlling the grade of a level under construction may be worthy of mention. The average miner, working in a level, has very little idea of grade, except as he sees the water run; and although the average grade may be very accurately controlled by the chain and leveling-instrument, there may occur very annoying variations between the visits of the engineer, particularly if the work is rapid. One must change these at much expense, or leave a permanent defect in a track over which many thousand tons of material may have to be moved. The grade of the level having been determined upon, a wedge-shaped straight-edge is prepared of convenient length, say 12 feet, wider at one end than the other by the amount of the grade in its length. Thus, if the grade is 1 in 400, and the straight-edge 12 feet long and 6 inches wide at one end, it would be 6.36 inches wide at the other end. The miner has simply to drive wooden leveling-pegs about 12 feet apart, level-

ing the top of the straight-edge with a spirit-level, with which he is provided, and driving the front peg down or cutting it off at the proper height. The miner has no linear measurements to take, as the exact distance apart of the leveling-pegs has no influence upon the grade. It was surprising to find how uniform a grade was thus obtained, and how slight a correction was required by the later instrumental surveys.

Mr. Scott: Mr. Hungerford admits that the greatest angle of depression possible with his instrument was 52°. By force of circumstances, then, he was required to employ the *Gradbogen* in connection with it, to determine dips as great as 75°—as an expedient, I should say, rather than a convenience.

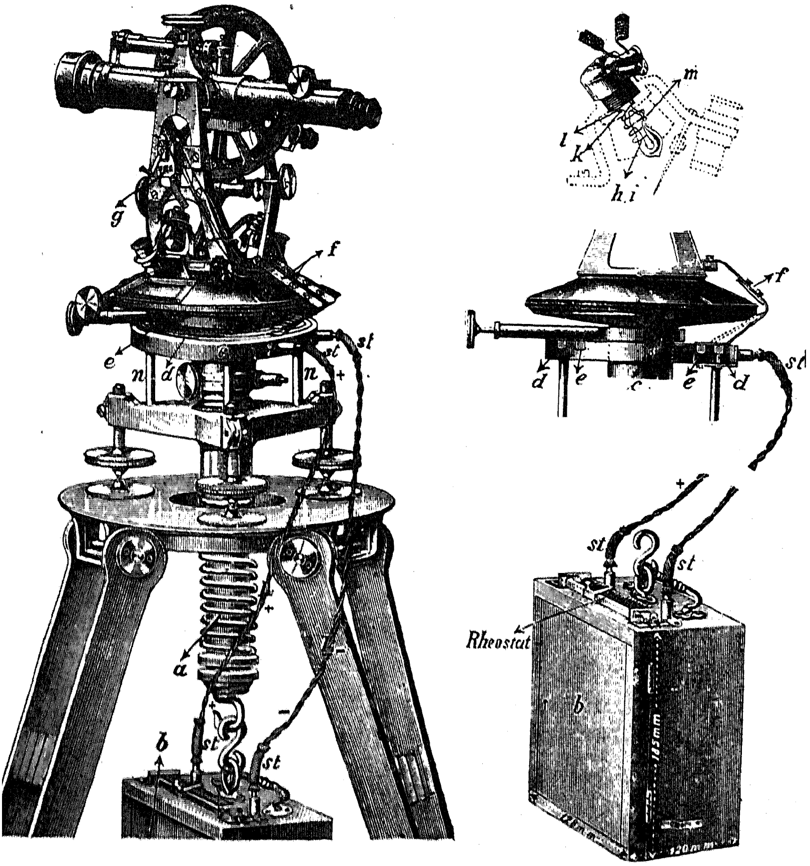
I am convinced that in the use of fixed reading-glasses there is no danger of losing them; that they are always in focus, that one hand, which would otherwise be engaged, is left free, and that a considerably higher power is possible, while the field still remains flat though somewhat diminished in size. Strictly speaking, fixed reading-glasses with a properly adjusted reflector, mounted behind them upon the radial arm of the socket, are a European innovation; and while my previous remarks were based upon an unsuccessful experience, it may be that with the great majority of American engineers I shall some day learn to adopt them. If Americans were generally more eager to adopt some of the more cumbersome and tedious of the German appliances and methods there would be no occasion for a diversity of opinion as to the correct method of illuminating and reading the verniers.

Herr Max Harrwitz has sent me from Berlin a description of Jahr's theodolite,* in which we have an instance of the extremes that are resorted to by the profound and ingenious Germans to effect a desired end. Suspended to the *Stengelhaken* (*a*, Fig. 84) is a small wooden box in which the electric current is produced in two ½-ampere accumulators that are set into hard-rubber cells. From this source two leading wires (*L*), positive and negative, are led each to one of two metal rings (*d* and *e*) that are separated by a little strap and countersunk into a hard-rubber plate (*e*). The connections of the leading wires

* Given in *Der Mechaniker*, vol. vi., No. 18, Sept., 1898 (from *Zeitschr. für Vermessungswesen*).

with the accumulator poles are made through casings at *st.* The hard-rubber plate is attached by three screws (n) to the base of the theodolite, and is perfectly concentric with the axis of the instrument. Upon the metal rings revolve, as desired, two contact springs (f) which are rigidly attached to the upper part of the theodolite, and by means of wires are connected with the

FIG. 84.



Illuminating Apparatus of Mine-Surveyor-General Jahr, of Breslau, Germany.

switch (g) and the lamps (h and i). By the switch either of the lamps can be turned on as required. The portable box (b), including accumulators and fixtures, weighs about 2.75 kg., or a little over 6 pounds. On the upper side ot the box is a rheostat to regulate the current. Both incandescent lamps may be fed from 8 to 10 hours continuously, so that if one required two

minutes to read both verniers, one charging of the accumulators would be sufficient for from 240 to 300 readings.

Of late several American engineers have been using small portable electric lamps, of the dry storage-battery type, with great advantage and convenience. The one used with much satisfaction by the writer is made by the American Endoscopic Co., of Providence, R. I. It weighs only 0.6 kg., and has a small, 8-candle power incandescent bulb with silvered parabolic reflector, that will burn continuously for 8 hours. The lamp has two batteries, one of which may be in use while the other is getting charged. A small switch at the side of the box turns the light on or off as desired, the current being continuous and the illumination brilliant. The entire length of the box is 6 inches, and, having a cross-section of only 1¼ by 3 inches, it can be very conveniently carried in the pocket. There is a detachable bulb at the end of a flexible cord, which may be arranged so as to leave both hands entirely free.

The chief merit of this lamp consists in the great convenience of its small size compared with its efficiency.

Another portable electric lamp is made by Elmer E. McIntyre, of Pittsburgh, Pa., and has a small bulb and white enameled reflector mounted on a stick-pin, so that it may be attached to the hat or any part of the clothing. The battery-case is strapped around the waist, and weighs 1.4 kg. It is of 4 c. p., and is designed to burn 10 hours, though in reality it falls decidedly short of that. To recharge the battery, it is removed from the case and the positive and negative poles are connected, by means of a specially provided intermediate socket, to an incandescent lamp on any 110-volt direct-current circuit. The amount of voltage and amperage that the larger lamps consume afterwards passes into, or through, the coils of the battery.

By the use of such portable electric lamps, the dimness of flickering candle-lights, the dripping of grease and the crude features of all other methods of illumination are forever done away with, except for those who will persist in magnetic surveys and the necessary bulky copper oil-lamps. But in these cases may we not say, in general, that the method of illumination is in consistent keeping with this awkward system of surveying?

J. E. JOHNSON, Longdale, Va. (communication to the Secretary): The paper of Mr. Scott has evidently been prepared with much care, and displays such a comprehensive knowledge of the subject that one has a feeling of trepidation at criticising any part of it. Nevertheless, I am compelled to take issue with one paragraph, namely, the second on page 703, which is as follows:

> "In recent years the hanging-compass has been redesigned by Queen & Co., of Philadelphia, and is said to be still indispensable to certain surveyors in Virginia and Pennsylvania. The excuse for employing the hanging-compass in cramped and tortuous channels to-day, however, seems absurd; for the transit can be made to do the most reliable work, even when removed from the tripod, anywhere that a man can take it."

This paragraph indicates a misconception as to what is possible and what is commercially practicable; in other words, *what pays*. It also seems to indicate that the words "cramped and tortuous" might have decidedly different meanings in different mining regions.

There is no doubt that, given unlimited time and unlimited expenditure for general and local appliances and support, a transit-survey can be made of any hole that a man can crawl through; but there is also no doubt that, with a hanging-compass outfit, when running on short lines between definitely-located points, work which is substantially accurate and entirely within the needs of ordinary commercial engineering can, in many cases, be done in as many minutes as the transit-survey would require hours. To explain the circumstances under which this is true within the writer's own knowledge, it will be necessary to give a brief *résumé* of the paper to which Mr. Scott alludes, in a footnote, as having been published in *The Engineering and Mining Journal*, August 1, 1891, taken from *Transactions of the American Institute of Mining Engineers*.* The paper was written by Mr. Guy R. Johnson, then engineer for the Longdale Iron Company, of this place, now General Manager of the Embreville Iron Company, of Tennessee, and the mines described by him were those of the former company.

The mines, like others in the Oriskany or brown ore-deposits in this State, have for their objective a stratum, rather than a

* *Trans.*, xx., 96.

vein, of ore taking the place of the Oriskany sandstone, and lying immediately under the black slate [Rogers' No. VIII.]. The exact nature of the stratum as to thickness, dip, continuity, etc., varies in each case with the mountain in which the particular mine is located. Locally, the ore-stratum is vertical or even dipping *toward* the mountain at its southwest end, and gradually twists, like a huge "warped surface" or a helix of very high pitch, as it goes northeast, lying at an average inclination of about 35° at its extremity in that direction. The stratum is entered at intervals of 120 feet vertically by tunnels through the slate, which of course follow the ore after they reach it, generally keeping the bottom inner corner of the tunnel just along the foot-wall. The irregularities in places are extreme, the tunnel being in a number of places at right-angles to its proper general direction, and in a few, pointing the opposite way.

The main tunnels are connected at intervals of approximately 120 feet horizontally by a pair of upcasts—one called, locally, the "chute," the other the "man-way." Along with the main heading, after the ore is reached, is driven another about 20 feet above it, called the "air-way." Subsequently other levels are driven, all at intervals of 20 feet vertically, making, of course, five between each pair of main levels. It is impossible to describe the operation properly without some reference to time and the consecutive order of the operations, and it should be said that the mine is worked down in successive levels, each main entry being driven when there is still several years' ore in sight in the one above. The main entry and air-way are carried on together, as stated, and as fast as they reach the proper points for the upcasts, these are started and cut through to the main entry next above for ventilation, etc. The levels above the air-way are driven approximately in the order of their heights above the main entry, so that it may be a year or two after the main entry passes a given chute before the "100-foot level" reaches it. After a given section has been developed in this way to its extremities, the 20-foot pillars are "split," and then "robbed," beginning at the top, of course, and working down.

In surveying the mine a transit-line is first run with some care in the main entry, putting nails in the ties, instead of the

collars or "caps," as the ties are very much less likely to move or break; and in using wire nails instead of tacks it is remarkable how seldom points are lost, even after the lapse of many months, or even two or three years. The passing of all chutes and man-ways is noted on the transit-survey.

Starting at these points, a string-survey is taken through them, taking the bearing, inclination and length on the string. The passing of all the levels is carefully noted, and the distance of the string above the bottom of the level at the point taken as the intersection is noted also. Subsequently the compass is removed from the gimbals, fitted with standard-sights, and mounted upon a small tripod with a ball-joint connection. The levels above the main entry are then run out, sighting from the compass forwards and backwards at lamps held in the center of the level, thus taking both a "back sight" and a "fore sight," as with a transit, but only setting up at alternate stations. This saves one-half of the number of "set-ups," and avoids the error of not setting the compass vertically over the point last sighted at, an error liable to occur when only taking foresights. The points noted as the intersections when making the string-survey are located on the tripod-compass-survey of the levels by eye, and notes of their location taken.

This will doubtless seem to many mining engineers a barbarous method, and from the point of view of absolute accuracy undoubtedly it is, as compared with making a transit-survey of the whole mine—chutes, secondary levels and all; but the remarkable thing about it is the accuracy which may be obtained in this way. It should be noted that the length of each individual string-survey is only from 120 to, at most, 250 feet, and that when the upcasts are cut through to the main entry next above, the upper end of the survey can be connected with a known point on the transit-survey of that entry.

By the aid of a trigonometer, or mechanical traverse-table, the horizontal and vertical lengths of the inclined sights are obtained and plotted; first as a "plan," or map, reduced to a horizontal plane, and from this and the vertical components of the sights an elevation is constructed; also cross-sections, when necessary. It should have been said also that a line of levels is run into the main entries, and the elevation of the top of the

rail is taken at all chutes, to form the basis for the elevations derived from the respective string-surveys.

Moreover, with regard to the barbarous practice of locating the intersections of the upcasts and secondary levels at the same point in space by eye, I would say that never more than a thousand feet per year of the mine are opened up in the way described; that, as the survey is brought up to date every year, there are comparatively few new upcasts and a correspondingly small number of intersections to carry in one's head during the period elapsing between making the string-survey of the upcasts and the compass-survey of the secondary levels; and that, owing to the rapidity with which the work can be done in this way, this period is very short—not over a few days. It is needless to remark that one's memory would not be equal to the task for the period required if a transit were used.

It is also to be noted that the iniquity of using this method is largely counterbalanced by the fact that a variation of a few inches, or even a couple of feet, with the compass will simply result in displacing the line parallel to itself by that amount; whereas with a transit, on lines of the same length, averaging, perhaps, 20 feet, the same error, swinging the entire remaining portion of the line through a corresponding angle, would make the results so obtained worse than useless. Again, there is a fair chance with the compass that the errors will balance one another, but practically none with the transit.

As a matter of actual experience, surveys so made plot on paper with a degree of accuracy that is almost surprising, the intersections, as noted on the two surveys in which they occur, coinciding so closely as frequently to be almost within the errors of plotting. For the purposes for which the survey and map are designed—that is, to show the progress and shape of the mine, to give directions for cutting new passage-ways of moderate length when necessary, and to show the mine as it practically is—this system of surveying is as useful and satisfactory as it would undoubtedly be preposterous if applied for the location of points to hit exactly with vertical bore-holes, or for similar absolutely accurate work.

It would undoubtedly be possible, as observed in the beginning, to carry a transit-survey through these mines or any others; but the difficulties of the process would be immense. The

chutes and man-ways are "cribbed up," when it is necessary to timber them, $3\frac{1}{2}$ feet square inside. They follow the flexures of the foot-wall of the ore in one direction, and sometimes, unfortunately, the equation of personal error of the miner or foreman in the other, and occasionally even both at once; so that the bends are sometimes very short, especially in the vertical plane. Frequently, of course, these bends occur when the chute is nearly or quite vertical, and the difficulties of getting satisfactory readings with compass and clinometer are very great; and a survey of accurately-fixed points with a mining-transit, capable of use throughout the entire vertical plane, dismounted from its tripod (the only way it could be taken through or set up), would be a matter of an indefinite amount of preparation for each sight, and unlimited time and expense. In the matter of time, it is necessary to note that the chutes are, normally, more or less filled with ore, and must be specially emptied, with inconvenience and loss of time, in order to be surveyed at all.

Something over a year ago it became desirable to connect two main entries by a transit-line, and so a man-way was cut with especial care to keep it straight and have the inclination sufficiently uniform to be within the vertical range of a standard transit (without other attachment than those appertaining to the ordinary horizontal and vertical circles); but in spite of these precautions, and the simplicity of the problem presented in surveying the opening, the time consumed in the operation was an earnest of what it would be to do the same thing in steeper and more tortuous places.

In view of these facts, I must beg Mr. Scott to believe that there is a field, small in size and importance as compared with the Lake Superior region, perhaps, in which the hanging-compass has a respectable, if not exalted, sphere of activity and usefulness still left to it, and in which, for the purposes of what may fairly be called commercial engineering, it is far better than any form of transit ever yet designed or ever likely to be.

Julius Kellerschon* (communication to the author): Being assured, by the contributions from Messrs. Hungerford and Johnson, that in various parts of America the old German method of cord-surveying is still used to apparent advantage for certain kinds of work, I take this opportunity to submit

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what I believe to be the first English translation of the text in Prof. von Miller-Hauenfels's work* that relates to the rules of which Mr. Scott has spoken on page 687.

It is not quite just to ascribe to Prof. Hauenfels the entire credit Mr. Scott has given him; for investigations in a scientific and systematic manner had been conducted some time before the beginning of this century, as will appear below. But the Leoben professor, no doubt, was the first to get complete information on the subject in comprehensive form for the use of the student and practitioner. He closes his remarks, however, with an observation to the effect that the varying tension on the cord, its hygrometric conditions, etc., must still be considered before the discussion can be accepted as closed. He says:

"The experiments executed in this line show that the *Gradbogen* suspended in the exact center of the cord will cause the vertical component to be too small and the horizontal too large; but the corrections which practical work actually requires are considerably greater than those provided for in the theoretical formulas of the catenary curve. The reason for this is that the hook at the higher end depresses the cord more than the lower one. If, in the accompanying diagram (Fig. 85), *a* and *b* are the points from which the *Gradbogen* is suspended; *c*, the point from which the plummet is suspended; *d*, the center of gravity of the *Gradbogen*; *Q*, the weight of it; *q*, the weight of the plummet, and *f*, *h*, *i* and *g* the projections of the points *a*, *c*, *d* and *b* on a horizontal line, then the weight which draws vertically at the point *b* may be expressed by $\frac{1}{fg}(fh \cdot q + fi \cdot Q)$, and the weight which draws vertically at the point *a* by $\frac{1}{fg}(hg \cdot q + ig \cdot Q)$. The sum of these two expressions would be, as it ought to be, the total weight of *Gradbogen* and plummet. As *fh* and *hg* do not differ much in length, and the weight *q* is inconsiderable as compared with *Q*, it is mostly the leverage *fi* and *eg* which decides the depression caused by the hooks *a* and *b*. Thus the higher hook, *b*, will depress the cord in proportion to the degree of the inclined angle. In a very steep angle it can reach a condition where *ig* will be negative; that is, the lower hook will have a tendency to rise above the cord, and in such cases it must be fastened to prevent this.

FIG. 85.

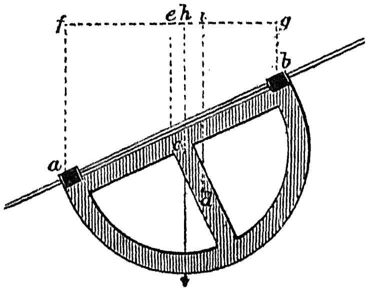

Diagram of Gradbogen.

"The first experiments along this line were made several decades ago by the late Mr. Florian, of Bleiberg, in Carinthia. He made known to several of his acquaintances the results of his very laborious and precise experiments, but I was unable, in spite of many inquiries, to obtain a copy of his original manuscript.

* *Höhere Markscheidekunst*, Albert Miller von Hauenfels, Wien, 1868, pp. 288.

The resulting rule, however, was communicated to me by the kindness of Berghauptmann E. Hübel, of Olmütz, who found it in the memoirs of his late father-in-law, Bergrichter von Hohenfels. Florian's rule is as follows:

"'*To find the true vertical angle of the cord, the Gradbogen should be suspended approximately one decimal inch from the center of the cord toward the higher end of it for every degree of inclination, so that, at 45°, it will be suspended 50 decimal inches from the center of the cord.*'

"The weight of the *Gradbogen* is in this case taken as 7 *Loth.** The length of the cord is not given in Florian's calculations; but it seems that it did not exceed 8 *Klafter* (fathoms); for there is a remark to the effect that this length should not be exceeded in determining vertical heights.

"In the *Berg- und Hüttenm. Zeitung*, No. 7, 1862, Prof. A. Junge published experiments also along this line. He measured accurately the vertical and horizontal components of cords, 3 to 7 Freiberg *Lachter*† long, subjected to a tension of 20 kg., and from these figures calculated the true length of the cord, as well as the angle of inclination, comparing these with the angles as actually read. We take from his table the following figures, and add a few columns, which will form the basis of our further consideration:

Number of Experiment.	Length of Cord.	Inclined Angle. Calculated.	Inclined Angle. Angle as Read at Center of Cord.	Calculated Suspension Point for Gradbogen.	Average Values.	Suspension Point Determined by Factor .003 for each Degree.	Average Values.	Suspension Point Determined by Factor .004 for each Degree.	Average Values.
1	6.80	1° 41′	1° 39′	0.552		0.505		0.507	
2	6.81	3° 22′	3° 21′	0.526		0.510		0.513	
3	6.83	5° 03′	5° 03′	0.500		0.515		0.520	
4	6.85	6° 43′	6° 42′	0.531		0.520		0.527	
5	6.87	8° 22′	8° 21′	0.539		0.525		0.533	
6	6.90	10° 00′	10° 00′	0.500	0.525	0.530	0.518	0.540	0.523
7	6.94	11° 38′	11° 36′	0.569		0.535		0.546	
8	6.98	13° 14′	13° 12′	0.564		0.540		0.553	
9	7.03	14° 50′	14° 48′	0.592		0.541		0.559	
10	7.09	16° 23′	16° 21′	0.581		0.549		0.565	
11	7.15	17° 56′	17° 54′	0.569		0.551		0.572	
12	7.21	19° 28′	19° 21′	0.558	0.572	0.558	0.547	0.578	0.562
13	6.17	21° 54′	21° 51′	0.600		0.575		0.593	
14	6.09	23° 38′	23° 36′	0.563		0.571		0.591	
15	7.43	23° 48′	23° 45′	0.586		0.571		0.595	
16	7.15	26° 31′	26° 33′	0.526		0.580		0.606	
17	7.60	26° 31′	26° 30′	0.616		0.579		0.606	
18	6.79	30° 23′	30° 21′	0.563	0.576	0.591	0.578	0.621	0.603
19	6.38	32° 12′	32° 09′	0.600		0.596		0.629	
20	5.72	36° 28′	36° 24′	0.653		0.609		0.640	
21	5.56	37° 42′	37° 39′	0.667		0.613		0.651	
22	5.40	38° 58′	38° 57′	0.587	0.627	0.617	0.609	0.656	0.645
23	4.67	46° 44′	46° 42′	0.598		0.640		0.687	
24	4.63	48° 35′	48° 33′	0.598		0.646		0.694	
25	4.40	50° 32′	50° 30′	0.598	0.598	0.651	0.646	0.702	0.694
26	3.94	59° 32′	59° 30′	0.607		0.678		0.738	
27	3.86	62° 06′	62° 03′	0.630		0.686		0.748	
28	3.77	64° 48′	64° 48′	0.500		0.694		0.759	
29	3.49	76° 46′	76° 45′	0.720	0.631	0.730	0.697	0.807	0.763

* One German pound or ½ kg. is equal to 16 *Loth.*

† One Freiberg *Lachter* is equal to two *mètres*, or 6.56 feet.

"The first four columns require no explanation. The fifth shows the point of the cord, expressed in decimal parts of it, at which the *Gradbogen* should be suspended in order to obtain a true reading, as shown in the third column.

"The values in the fifth column have been computed by Prof. Junge from readings made at the center and both ends of the cord, according to Lagrange's interpolation-formula. We agree with Prof. Junge that the point for the suspension of the *Gradbogen*, under the same conditions, should be removed from the center upward, in proportion to the length of the cord, which theory has also been verified by Borchers (see *Berg- u. Hüttenm. Zeit.*, No. 25, 1863); and it is to be pronounced an omission by Florian that in formulating his rule he took no account of this important fact. On the other hand, we take issue with Prof. Junge that he has not sufficiently emphasized the effect of the increasing vertical angle upon the correction to be made, to which Florian has attached the most importance. In a word, Florian says the *Gradbogen* should be suspended one decimal inch from the center for every degree of inclination; while Junge summarizes his experiments with the assertion that it should be suspended, on an average, 0.58 of the length of the cord from the lower end.

"To combine these, we must consider whether the absolute values given by each correspond. For the angle of 45° in Florian's rule, with the correction of 50 decimal inches, the values given by each are respectively as accurate as could be desired. By Junge's twenty-third experiment, in which the angle is 46° 42′, the distance of the suspension-point from the center is given at 0.098 of the length of the cord; that is, in this case, $4.67 \times .098 = 0.458$ Freiberg *Lachter*, or $0.458 \times 1.024 = 0.47$ Weimar *Klafter*. Now, according to Florian, the suspension-point should have been 0.52 Weimar *Klafter* from the center of the cord; but if we consider that Florian used a longer cord, as well as that the average values in the sixth column, twenty-third experiment, represent one of those cases in which the point of suspension has been given by Prof. Junge, no doubt, a little too low, we may safely say, as to Florian's correction-limit, that nothing better could be desired.

"Using Florian's rule, we find that by it, and on the basis of Junge's experiments, the best results are obtained if the number of degrees and fractions thereof, as read at the center of the cord, are multiplied by the factors 0.003 and 0.004, and to this result are added 0.50. Figures obtained by this calculation are shown in columns 7 and 9. In columns 8 and 10 the comparative average values show that up to an inclination of 15° the factor 0.004, and with greater angles the factor 0.003, give the best results. Therefore, to read the vertical angle as accurately as possible, the *Gradbogen* should be suspended toward the higher end of the cord at a distance from the center obtained by multiplying the length of the cord, at angles up to about 15°, by 0.004 for each degree, and for larger angles by 0.003.

"It might be said that, in the deduction of this rule, the weight of the *Gradbogen* and the tension in the cord have not been considered. But when two systems of experiments like those cited, made at different times and places, and therefore surely under very different circumstances, gave such similar results without considering the above factors, we are hardly justified in taking them into account."

P. & R. Wittstock* (communication to the author): We read in the *Engineering and Mining Journal* of January 16, 1897, and

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in the *Colliery Engineer* for February, 1897, descriptions of Mr. Scott's new mine tachymeter, which so recommended itself to us that we at once undertook its construction. In the meantime we have read Mr. Scott's paper, and have been in correspondence with that gentleman, and he has given us several ideas concerning this latest type described below; but we are particularly indebted to him for suggestions concerning the edge graduation for the vertical circle and the method of mounting a compass over the telescope, to take the place of the striding compass, which has not yet ceased to be popular in this country.

The extension tripod is made of seasoned maple, is of a light pattern, and closes up to three feet in length. The upper ends of the legs have wooden tongues inserted to prevent splitting. The tripod head is cast in one piece, and the connection of the instrument is established by a strong screw-thread of a few turns. This is as simple and effective as is possible, and possesses the advantage of never getting out of order.

The engineer, who has to work occasionally in a chilly atmosphere, will appreciate the unusual size of the four leveling screws. Under any conditions they are a great advantage in connection with instruments having very sensitive levels.

The compound vertical axes of the instrument are turned with the greatest possible precision, are fitted to each other with exacting care, and are of such strength as to give the whole instrument an uncommon rigidity and stability.

Both horizontal and vertical circles are divided on solid silver. The figuring on the horizontal circle runs consecutively from 0 toward the right around to 359° in a single row. That permits the opposite verniers, marked I and II, to be also single. This is the only safe, simple and systematic method, as the angles are always read from left to right, no matter what the size. There is never any danger of reading the wrong set of figures or the wrong vernier, as might happen with the double row of figures and double verniers, which were devised in the mistaken idea of being better adapted to suit all conditions. A special feature of our graduation is its remarkable exactness, which cannot fail to give satisfaction to the most critical and scrutinizing engineer. The figures are placed unusually close to the edge of the graduation, which fact we feel will be much appreciated by those who have experienced the

difficulty of reading the point of contact with long lines and distant figures.

The cylindrical ends of the horizontal axis rest in the Y bearings of the U-shaped aluminum standards. The bearings, one of them adjustable, have the usual covers, through which are inserted the friction screws with ivory points. The vertical pillars terminate in screw-threads, just like the extremities of the horizontal axes, to which the interchangeable auxiliary telescope and its counterpoise weight may be attached, and so revolved to any desired position. The pillars are made with large openings, and of such a shape (see Fig. 89) as to interfere as little as possible with the aiming of the main telescope.

Both telescopes are focused by a rack and pinion movement, and protected by a dust-guard slide that is not cut out to provide for the objective-end of the telescope bubble tube, as is very often done. We have crowded the telescope bubble as near to the ocular-end as possible (see Fig. 87), in order to accomplish this desirable result. In this position it is equally effective, and, besides, is more easily observed than when suspended exactly below the middle of the main telescope. All the optical parts are only of the first quality, and the magnifying powers, as stated in the following table, secure for the field of view an incomparable brilliancy; but, whenever we are called upon to employ a power one-third higher, nothing but satisfactory results are still obtained.

On one end of the horizontal axis is the vertical circle; on the other the gradienter screw, which also serves as the vertical clamp-and-tangent-screw. The beveled head is divided into 50 spaces, each of which corresponds to $\frac{1}{100}$ foot at a distance of 100 feet; or if the screw be moved through two entire revolutions, the horizontal hair of the diaphragm will travel vertically over the space of 1 foot, 100 feet away.

The figures placed on the vertical circle divide it into quadrants running each way, up and down, from the central zero-line. In this way an angle of elevation or depression may be read with the main telescope in either a normal or a reversed position. Mr. Scott says, in his estimation it is better to check a vertical angle by reading it in this way than to employ opposite verniers, which increase the risk of ruining the graduation.

by the grit that is deposited from percolating waters. For this reason one double vernier is provided; and it is now placed in a more convenient position for reading, as will appear shortly.

Table of Dimensions.

Sizes	A	B-1.	B-2.	C.
Horizontal circle, . . .	4 in.	4½ in.	5 in.	5 in.
Vertical circle, . . .	4 in.	4½ in.	4½ in.	5 in.
Main telescope (inverting), .	7½ in.	8 in.	8 in.	9½ in.
Magnifying power, . . .	18 diam.	20 diam.	20 diam.	22 diam.
Object glass, ...	1⅛ in.	1⅛ in.	1¼ in.	1¼ in.
Can be focused, . . .	down to 3 feet.			
Auxiliary telescope (inverting),	5½ in.	6 in.	6 in.	6½ in.
Magnifying power, . . .	12 diam.	14 diam.	14 diam.	16 diam.
Object glass, ...	¾ in.	⅞ in.	⅞ in.	1⅛ in.
Can be focused, . . .	down to 3 feet.			
Length of needle, compass attachment, ...	3¼ in.	3¾ in.	3¾ in.	4½ in.
Weight of instrument with attachments, ...	3.58 kg.*	......	3.95 kg.†	......

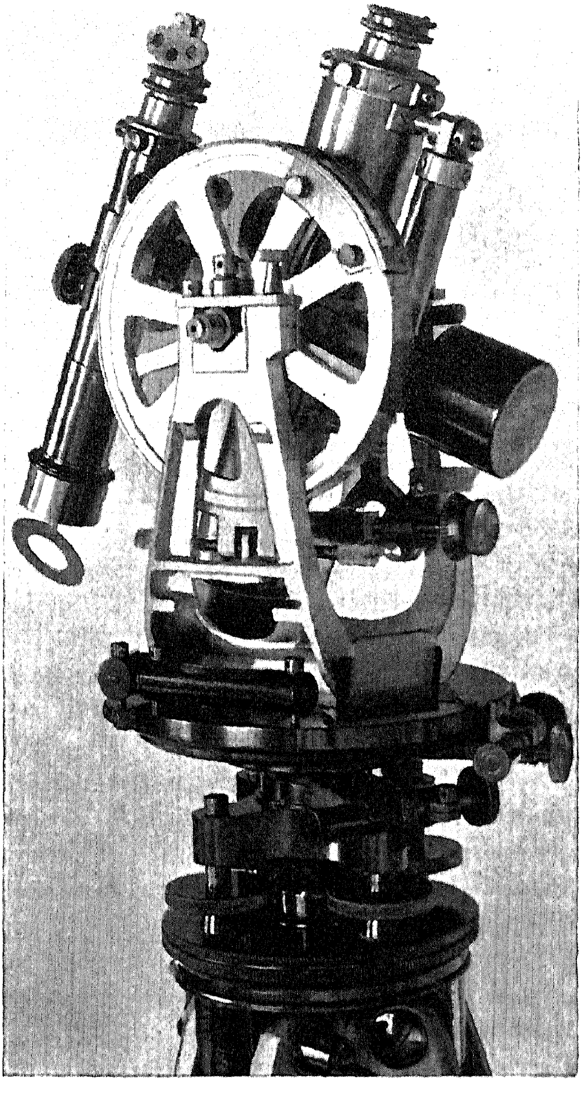
The only difference between B–1 and B–2, as appears, is in the size of the horizontal circle. In B–1 the verniers are placed on the top, as in Fig 86; while in B–2 they occur at the side, as in Fig. 87. This last arrangement gives us the opportunity of placing a larger and more delicate bubble on the plates, and indeed of presenting to the engineering profession a method of reading and illumination which cannot be surpassed. Its special advantages may be enumerated as follows: 1. It is obvious that the size of the graduation is larger without increasing the diameter of the plates. 2. The verniers can be placed at any angle to the line of sight. 3. The plate level may occupy its normal position, and need not be cramped, or made to extend over the edge of the plates to make room for the vernier-openings. 4. The diffusion of bright sunlight, or of artificial light underground, is more agreeable to the eye. 5. When not in use the reflector-shades are to be closed up, to protect the vernier.

Having given above a brief general description of the four types as we make them, we desire now to dwell in detail upon some of the more characteristic features of this new design, which we do not hesitate to say gives us the right and privilege

* 7.89 lbs. † 8.71 lbs.

to denominate Scott's mine tachymeter the most universally convenient and complete instrument ever constructed for mines.

Fig. 86.

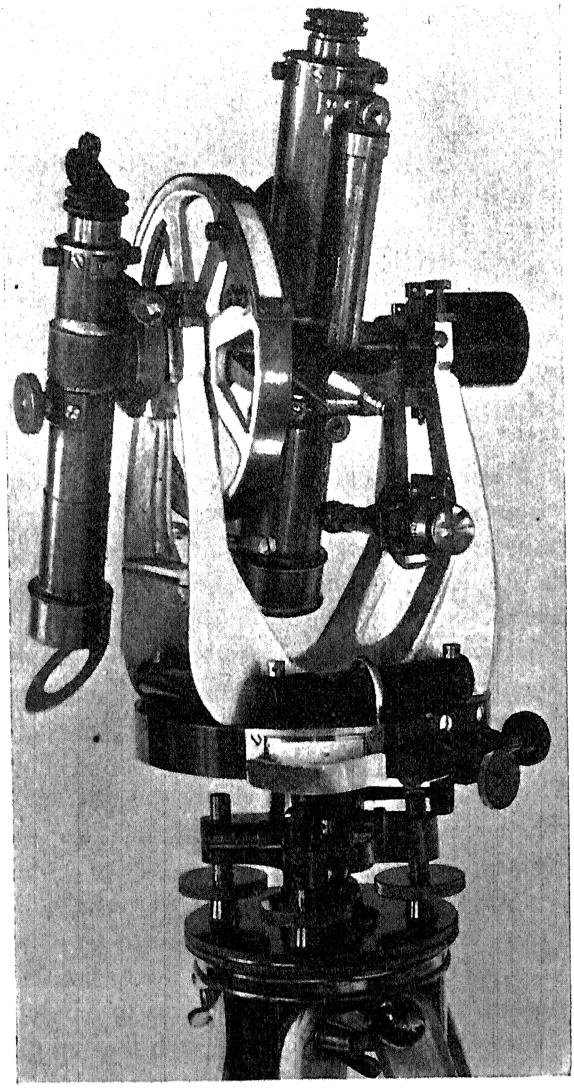


Scott's Mine Tachymeter, P. & R. Wittstock's Size A (4 in.).

The Interchangeable Auxiliary Telescope.—In America the auxiliary telescope has been in use for a great many years, but

never before has it been possible to use it in more than one position as the case might require. But here is an appliance

FIG. 87.



Scott's Mine Tachymeter, P. & R. Wittstock's Size B-2 (5 in.).

which can be used on the top, if a horizontal angle is to be read while the telescope is steeply inclined, or at the side, if an un-

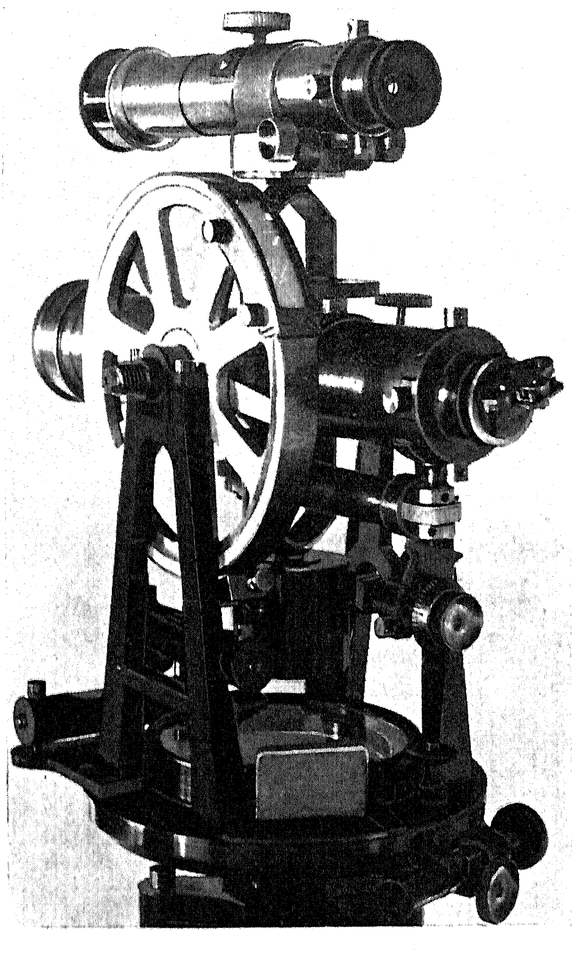
usually steep vertical angle is to be read; and in each case with positively no correction for eccentricity. It may be attached as desired to any one of the four radial arms of the main telescope, and ranged very quickly and accurately into perfect adjustment with it by two opposing thumb-screws, as shown in all of our illustrations. This adjustment for alignment is secured in a moment by sighting the main telescope at a distant light and bringing the auxiliary to bear on the same light. The necessity for any adjustment for absolute parallelism is now entirely done away with; because in reading vertical angles it is used only at the side, and in reading a horizontal angle at one of whose sides the telescope dips very low below the horizon, it is attached only at the top.

The Vertical Circle.—Generally it will be customary to use the auxiliary at the right side, opposite to the vertical circle; but if it should ever be found more convenient to attach it to the left side, as shown in Figs. 87 and 89, the edge graduation will never be found to conflict with the auxiliary so placed. But the most desirable point which Mr. Scott wished to develop here has reference to occupying a very cramped position in surveying a narrow and precipitous inclined shaft. The engineer in such a case may now make an observation through either of his telescopes, and read both the horizontal and vertical circles without moving in his tracks! The double vernier is carried by an aluminum frame, with ample means of adjustment, that protects the whole circle, and is placed in a convenient position at about 45° above the horizon. The opening is covered by a glass plate of a curvature corresponding to that of the circle, as is indeed the case with the verniers of the horizontal circle shown in Fig. 87.

Disappearing Stadia Webs.—When the diaphragm is made of extra thickness, and the cross and stadia-webs are mounted on opposite sides, so that each group may be focused separately with the ocular, it seems impossible to us to employ equally high telescopic powers satisfactorily in such limited dimensions as are usual in the ordinary size surveying instruments. If, for instance, the focus of the objective is 9 inches, and the telescope of 20 diameters power, then the focus of the first lens in the ocular will be $\frac{9 \times 2}{20} = \frac{9}{10}$ inch, and the distance of the

image from the first lens $\frac{9}{10 \times 10} = \frac{9}{100}$ inch. Consequently the thickness of the diaphragm must not be greater than $\frac{8}{100}$ inch, in order to leave a little space between the eye-piece and

FIG. 88.



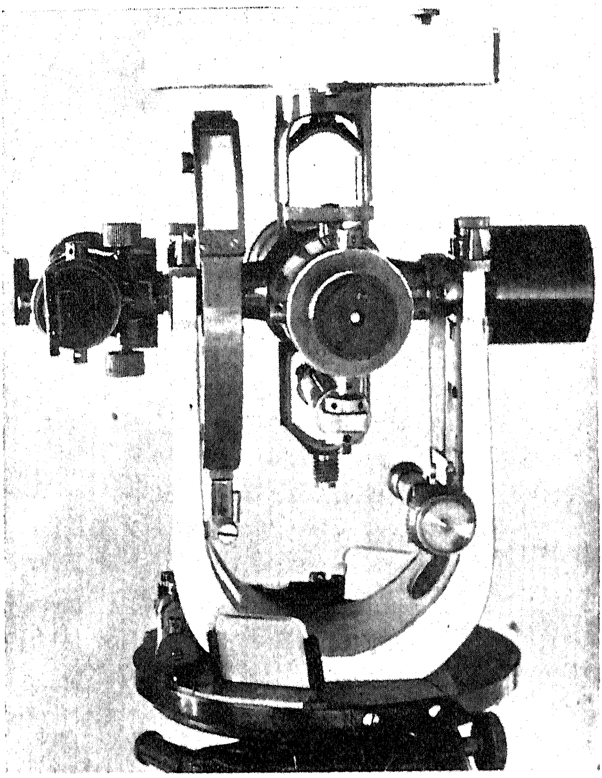
Scott's Tachymeter with Fixed Compass, made by P. & R. Wittstock.

diaphragm when the webs on the further side are in focus. Now, where is the room that should be allowed to suit the varying requirements of the eyes of different operators? Further than this, in such a case the webs that are out of focus are not far enough away to be entirely invisible, but blur the field of

view; and, besides, every time it is desirable to change from one set of webs to the other it is necessary to re-focus not only the ocular, but also the objective.

Our construction provides for the usual worm-thread focusing arrangement for the ocular, with ample play to suit the requirements of different eyes. The cross-webs are also mounted

FIG. 89.



Detachable Aluminum Compass, on Scott's Mine Tachymeter, made by P. & R. Wittstock.

in the usual manner on a diaphragm of the usual form and size. It has, however, a tube-like prolongation toward the objective, in which a second diaphragm moves that carries the stadia-webs. By moving this second diaphragm backward or forward, the stadia-webs are brought into the field of view, or moved entirely out of it. The screws which govern this motion from

the outside are of ample capacity to do this effectively. It will be understood that by this arrangement the cross-webs are never out of focus, and the adjustment of the line of collimation is, therefore, never impaired; since the eye-piece and object-glass always remain untouched.

Luminous Levels.—We have experimented considerably with luminous levels, and believe we have the honor to be the first house actually to introduce them as suggested by Mr. Scott. We have found that when exposed to a diffused dry light the luminous substance will act longest and best, and in the dark the divisions in the glass and the bubble itself appear quite distinct. When the action becomes weaker, and the luminosity fainter, it is with some difficulty that the bubble can be detected even with a magnifier; but the efficiency in this respect is restored by burning a strip of magnesium before the bubbles. However, it is only on rare occasions that this novelty will be an actual necessity, as Mr. Scott says, and no doubt what we have accomplished will amply suit all requirements.

The Compass Attachment.—To adapt this instrument to all the requirements as demanded still in Germany, England, and elsewhere, a circular compass-box, made of aluminum, is mounted on the upper vertical pillar, in the same way as the auxiliary telescope is attached. Most mine surveyors will have established near their works a true meridian determined by astronomical observation. The instrument should be set up at one end of this line, and, when the other is sighted through the telescope, the needle is brought to read upon the north point by means of the opposing milled-head screws below. By this same means any desired declination can be set off. As the compass-box is very light, weighing only .15 kg., or 5 ounces, there is no reason why observations through the main telescope should not be made at any considerable inclination with the compass still attached and the needle clamped; but before the needle is read, of course, the telescope must be brought back to a horizontal position. We also make a non-adjustable style, as shown in Fig. 80, which can be very easily and exactly attached, and can be carried in the pocket. Of course, there is no limit to the length of needle that may be used in this model, but we recommend those suggested in the table.

EDWIN J. HULBERT* (communication to author): I have been reading with much interest your able article in which (Fig. 31) you have included a description of an instrument which evidently you did not know was designed by the writer in 1854 to conduct surveys in the old Cliff mine on Keweenaw Point. The instrument was designed for the execution of a certain problem, and did it effectively and satisfactorily, though there may be means now in this progressive age still more accurate and rapid. I have fought my fight in the battle of life, and seek not for more recognition from the world than has been thus far observable; for be one an explorer, discoverer, scientist, historian, poet or author, he is bound later on by some investigator to be effectively "smashed." Iconoclasm is an attractive diversion, and will ever be in fashion; of course, there are some bugs larger than others, but each and every one remains still a bug.

It should be borne in mind in examining the problem I had confronting me that in the early days the phenomenal deposits of native copper, without precedent in the history of mining, were looked upon with much doubt as to their persistency in depth. Capital was not abundant—in most cases insufficient—skilled labor wanting, and, therefore, extreme economy enjoined. In fact, mining in the two decades following 1845 should be considered to have been explorative rather than exploitative; the shafts and drifts usually being small and cramped. Shafts were not sunk by an engineer's lines for a direct and regular course, nor for any particular grade, but followed the sinuosities of the footwall. The surveyor was forced to adapt himself to the exigencies presented by the rude bed-planking in the undulating shafts upon which the kibbals† slid to and from the different levels. Upon this no elaborate stations could be erected, and his almost invariable accompani-

* Retired mining engineer, a pioneer in the Lake Superior district, who discovered the celebrated Calumet copper lode on August 27, 1864; now residing at Via Nomentana 257, Rome, Italy.

† Kibbal. (A bucket or little tub. Armoric. Quibell, *idem.*) A bucket in which all work or ore is raised out of the mines. Gear barrels in the North of England. A whym-kibbal is a larger one, which belongs to the machine called a whym, and serves to draw water with, or bring up the ore to grass. Some of these larger barrels or kibbals contain 120 gallons when they are intended for drawing up water out of the mines. (Glossary. Pryce, *Mineralogia Cornubiensis*, London, 1778.) Written also "Kibble."

ments were smoke, foul air and precarious surroundings. Convenient and proper instruments were not at his command, and in fact, the necessity for the skill of a mining engineer was looked upon askance, and generally he was regarded by the miners as a genteel supernumerary.

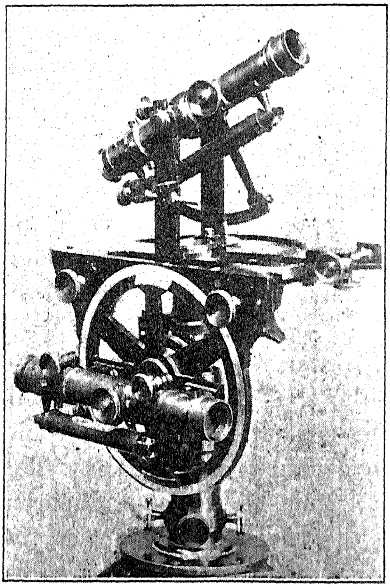
In those early days, mining captains and skilled labor for drift work, for shaft and gallery timbering, and for setting of pumps and of hoisting-engines were brought from Cornwall; many of the captains bringing with them the ordinary compass-dial, depending upon the polarity of the needle for direction and for repeating upon the surface a duplication of the tangents taken in the underground work. Seldom, if ever, was a back sight taken to test for magnetic variation. Where a pump, iron railways or other masses of iron occurred, their size and distance from the compass were very carefully measured, and upon the surface repetition similar pieces were placed. No triangular calculated work was attempted. Inclinations in the shafts were taken by means of the plumb-line, and horizontal offsets and measurements made with linen tapes, the age of which was not often questioned.

It was evident to me, that, in order to carry down a base through these cramped and irregular shafts, and from it to project a tortuous traverse many times its length, no accuracy could be obtained by use of the above enumerated means. The polarity of the needle upon or within these Lake Superior rocks was not to be trusted in the least degree; for, as the electric currents following either wall of the vein varied in force, the deflection also varied according to the distance of the instrument from it. The Cliff mine fissure-vein had a dip to the eastward varying from 88 to 86 degrees; consequently no sight on this inclination could be taken with the ordinary transit telescope.

Before designing an instrument suitable for this survey, some experiments had to be made. Having at hand a rude half-circumferentor, or goniometer, carrying the ordinary slit compass-sights, I attached to the side, overhanging the tripod, a half-circle made of wood, graduated with a penknife, and provided also with slit sights. Beginning on the surface, with the upper main sights bearing upon the base-line of the triangulation, I took the inclination with the side sights directed

towards a candle in the mine level below. Then I erected the instrument upon the point occupied by the candle, and with the two sights clamped in the position read at the surface, back-sighted to the surface point; and so established a line underground parallel (or as nearly parallel as it was possible for this improvised wooden model to make it) with the base-line of the surface triangulation. Repeating the work several times, making mechanical corrections for instrumental imperfections, I found the results fairly satisfactory; and being satisfied that with care in the manipulation of a good instrument of like nature good work could be done, I completed the design of the "double telescope transit" (Fig. 90) without the special interjection of French influences presupposed by you. The plans I laid before Mr. Young, of Philadelphia, personally, and he stamped them with his approval.

FIG. 90.



Hulbert's Transit, the "Lake Superior Pattern" of Fig. 31.

At that same visit, I think in 1854, I showed him my sketch of a transit with a base in the form of a horse-shoe mounted upon three leveling screws and an open-topped tripod-head, to be used for vertical sighting or for slight deviations therefrom; also another sketch of a transit with hinged standards, so that the telescope could be swung forward beyond the interference of the plates. These last two projects were rejected by this venerable mechanic; for he believed that he could not provide against the spreading of the horseshoe base, or construct a hinged standard so perfectly that it would always project a line twice alike. Mr. Walter Crafts, then superintendent of the old St. Mary's mine, but now of Columbus, O.,* I think, saw my

* SECRETARY'S NOTE.—Walter Crafts, born 1839, graduated C.E. at Troy in

drawings of the horseshoe transit. At any rate, the proposition for a design similar to Fig. 64 was extant nearly twenty years before Buff & Berger built that one for Mr. G. H. Crafts. The elder Young, now deceased, thought he could not, as I say, insure the absolute stability of the adjustments of either of these models.

In all my experience I have always discredited the efficiency of plumb-lines in shafts of any considerable depth, believing that greater accuracy could be obtained by a sight through a telescope adjusted to the nadir. After "holing" through to the Howe-shaft at the Cliff mine, I tried to close the survey instrumentally by dropping plumb-lines 630 feet in length. The plummet was suspended successively in water, molasses and diluted tar. The air currents were then entirely cut off, but, after several hours' waiting, in each instance the lines had not assumed absolute rest. We next tried the falling of a well-turned plummet from the top of the shaft to its bottom, where we placed a bed of clay to receive the impression. In several trials, however, we did not succeed in getting it to drop twice in exactly the same spot, although we burned off the thread that held it at the surface. But with the instrument (Fig. 31 or Fig. 90) very carefully leveled, and sighting down repeatedly with the zero of the limb turned respectively to the four cardinal points of the circle, we found the four points thus established to coincide very nearly. I do not believe that a plumb-line of any considerable length is going to obey the desire of the engineer so far as to vibrate precisely in any one direction; and I fancy that should Dr. Schmidt's apparatus (Fig. 27) be opened out from the plumb-line after it was supposed to have come to rest, it would begin of itself to renew its oscillations along directions governed apparently by no fixed rule.

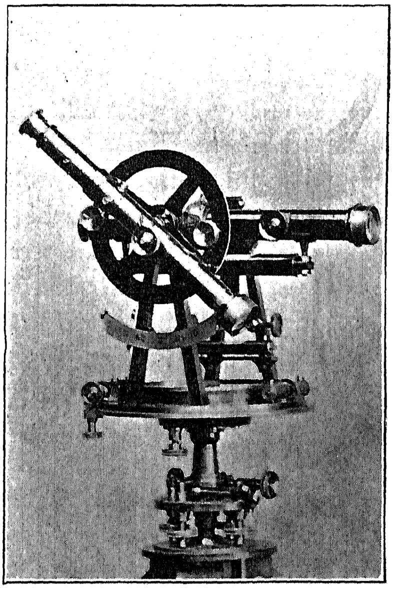
I should place more reliance upon a downward sight through a properly constructed and accurately adjusted telescope than in the repose of a plumb-line. We trust the telescope for the measurement of all horizontal distances, and we never question its accuracy in taking inclined angles and observations; now, therefore, why not accord it the same confidence in taking a

1859; studied at Freiberg in 1861–62; afterwards went to Lake Superior; lived several years at Columbus; and died August 2, 1896. For these facts I am indebted to Mr. B. S. Lyman of Philadelphia, Pa.—R. W. R.

truly vertical sight? Except for moderately short distances, I always considered the plumb-line a positive nuisance, a consumer of time and a disagreeable tester of patience.

The survey for which the instrument in question was made was one in which cross-cuts from the 30-, 40-, 60- and 70-fathom levels had to be driven back to the position of Avery-shaft (vertical), where we had seven gangs of miners, before the work was finished, raising and sinking against one another,—with an ultimate error of but 4 inches. That may be considered very reasonably close, when mud, slime, smoke and careless, ignorant assistants are given their place in the conditions that militate against one's chances for success.

FIG. 91.



Hulbert's Original Side-Telescope Transit.

In a second survey, involving a traverse of nearly a quarter of a mile, the error in closing was about 3 feet,—not quite so successful; but one cannot hit a bull's eye every time, even under the most favorable circumstances. Put a "newly-fledged chicken" from the Michigan College of Mines into such shafts as we had on Lake Superior forty years ago, and I fancy he would be very careful how he handled his few trumps.

It is particularly fitting to remark here, in this contribution to your paper on the evolution of mining instruments, upon how my second design was evolved from this first parental instrument. In 1856 we were making ready to "hole" into the Howe shaft of the Cliff mine at the 60-fathom level, and for this special piece of work, in that year I designed, and had Young make for me, what was, to the best of my knowledge and belief, the first application of the *side* auxiliary telescope. It is reproduced here in Fig. 91 from a photograph preserved and

kindly loaned by Mr. Young, and represents the ordinary flat-center transit instrument of that day with the second telescope mounted at the side. The tripod legs, as was then general, were of solid rigid pieces; though we had those in use constructed of three brass tubes sliding one within the other. The shifting tripod-head was also made at my suggestion by Young, who reaped the pecuniary benefit of its well-merited subsequent popularity. I never occupied myself with the idea of patent right and profit, as you assure me has been the case with yourself.

The method of mounting the auxiliary telescope prostrate upon the vertical circle was very similar to that pursued in my first instrument (Fig. 90), except that it was removed just far enough to escape the edge of the plates. But the combination was mounted now in a more stable position at one extremity, and concentrically with the axis of revolution.

I suppose, in the ethics of instrumental construction to-day, it would be considered necessary to counterbalance with a weight opposite, or at least to put the vertical circle at one side and the auxiliary telescope at the other; but we could not arrive at absolute perfection at once and leave nothing for posterity to accomplish.

With the improvement of the original instrument, however, as now accomplished by you in the "Scott tachymeter," in its solidity and perfect construction, the engineer should be quite content to undertake the solution of the most difficult problem ever presented in the mine.

SECRETARY'S NOTE.—Further discussion of Mr. Scott's paper will be published in vol. xxx. of the *Transactions;* and it is intended to issue subsequently a separate volume, containing Mr. Scott's original paper, together with the whole of its discussion.

Important Results Obtained in the Past Fifteen Years with the Stiff and Heavy Rail-Sections.

Discussion of the Paper of P. H. Dudley, New York City. (See p. 318.)

JOHN BIRKINBINE, Philadelphia, Pa.: We have in the Institute two Dudleys—Dr. Charles B. Dudley, who has so thoroughly studied the chemical composition and physical behavior of rail-steel, and Dr. P. H. Dudley, whose investigations and

suggestions as to the weight and form of rails, and their behavior in the road-bed, have been not less important. In my judgment, the improvements which the latter has brought into general use have probably accomplished as much for the increase of both speed and safety as any inventions that have ever been made in railroad engineering.

William Kent, New York City: Is the total stress given by Dr. Dudley's tables tension or compression?

Dr. Dudley: In order to get the total stress for the entire locomotive, we add the tension and compression together. This does not, of course, represent the stress on the rail at any one point and time. In my tables you will find that the stress on the 80-pound rail rises as high as 30,000 pounds under a driving-wheel. It is only because such stresses are of short duration that the metal will stand them.

Another fact as to the breaking of rails is, that most of our rails now break during the great falls of temperature. We used to consider only the effect of the normal wheel-stress; but there are also the effects due to the condition of the track, and the tensile stresses set up in the rails before the ends "render" in the splice-bars. In the winter season, we often have a fall of perhaps a hundred degrees in a week; and before the rails have rendered in the splice-bars, as the effect of that cold wave, another cold wave comes along, and the rails often break from a check that had been started by the previous "cold snap." I have known a number of instances in which the effect of a cold wave could be traced for two years at least, by the oxidation of the check. The result of the falls of temperature is to add many thousand pounds to the stresses in many of the rails.

Dr. R. W. Raymond, New York City: Some years ago it was questioned whether the breaking of rails in very cold weather was really due to the effect of low temperature upon the physical qualities of the metal itself. If I remember correctly, experiments showed that wrought-iron or steel was not rendered more brittle by ordinary changes of temperature, say down to zero, Fahr., or a few degrees below; and that the chief cause of the breaking of rails during "cold spells" was

the rigidity of the frozen road-bed, coupled with the imperfect laying of the track, which made so loose a contact with the bed as to subject the rails to terrible shocks from the impact of the wheels when the frozen earth would not yield to the blow. With our more perfect road-beds and heavier rails, we have, no doubt, less breakage from this cause; and the question of the actual effect of temperature can be investigated, perhaps, with greater precision. That there is a temperature which destroys the cohesion of steel is indicated by the striking results produced by liquid air, though these results may not be due to low temperature alone. The effects produced upon non-metallic fabrics, for instance, may indicate another cause. By the way, I understand that the action of liquid air upon different metals and alloys is highly variable; and I would repeat here the suggestion, recently made to me by one of the professors of Columbia University, that an investigation of this question would be a highly valuable and fruitful labor for any member of the Institute so situated as to be able to undertake it.

Dr. Dudley: As I understand it, the temperature produced by liquid air on a piece of steel is so low as to contract it below its elastic limit, and it cannot then be restored to its original elasticity. This is not the case with the effect of the cold weather on steel rails. A little check, almost too minute to be seen, may be produced under a passing wheel; and the next "cold spell" may cause complete fracture under another wheel.

Prof. H. M. Howe, New York City: Referring to Dr. Raymond's suggestion that the brittleness caused by liquid air in steel may not be due to low temperature alone, I would say that so far as my work with liquid air has gone (which, indeed, is not very far), I have seen nothing to indicate that the brittleness which it causes in iron or steel is due to anything else than the direct effect of the low temperature itself.

Such a stress as Dr. Dudley gives, if frequently repeated, should break in a very short while any steel rail now in use. I suppose the reason that this stress does not actually cause rupture in rails is, that it occurs at such great intervals that

before a sufficient number of applications of it have occurred to break the rail through exhaustion of "endurance," the rail itself has been worn out through abrasion. I would like to ask Dr. Dudley whether the fiber-stress on the top of the rail, when it is bent up, is anything like as great as the fiber-stress on the flange of the rail. I understood him to say that the fiber-stress in the flange was sometimes as high as 60,000 pounds per square inch. I should think that stress, if rapidly repeated, would very quickly break steel, or crack any rail now in use. Of course the repetition comes slowly in the case of rails; and the question arises, whether it would not be many years before the innumerable repetitions of such stresses required to break the rail would have taken place, and whether the rail would not have been worn out meanwhile through other causes.

DR. DUDLEY: I think that view has much truth in it. If you have many repetitions of stresses up to 60,000 pounds, you must expect to break something. Stresses as high as 60,000 pounds, however, have not been found on main lines. In a worn locomotive-tire there are apparently little flat spots; and the stresses produced by a worn locomotive-tire often go as high as 40,000 pounds. I have known of mail-cars, coming from the West over long routes, having "flat wheels" which produced stresses up to 40,000 pounds. If the rails do not have time to recover from such stresses, they will certainly break after a certain number of repetitions, in accordance with Wöhler's law. What I am trying to do, by accurately measuring and reporting such stresses, and indicating their cause, whether in the road-bed, the rail or the wheel, and by introducing heavier rails, is to reduce the number of breakages as much as possible.

WILLIAM KENT, New York City: In one case which I examined there was a rest of two or three hours between the stresses, and the metal came back to its original condition. I made some experiments, one of which was subsequently reported by Prof. Thurston, showing that a rod, bent to a certain degree of deflection by a given stress, and then let alone, required several hours to straighten out and recover its normal condition. This indicates, in my opinion, that a rail stressed

to 60,000 pounds would recover from that stress if not again subjected to similar stress within a short time.

DR. DUDLEY: It might be two or three days, or a week, in ordinary railroad practice, before a stress as high as that occurred again.

It may be interesting to members to see a picture (Fig. 1) of the standard train of the New York Central and Hudson River Railroad as made up for the transportation of grain. It consists of 80 cars, of 60,000 pounds capacity each; its length is 3300 feet, or five-eighths of a mile; and its gross weight is 3700 tons. On the "Dudley" $5\frac{1}{8}$ inch smooth 80-pound rails, the resistance per ton of train is, at the speed of 20 miles per hour, 3.5 pounds.

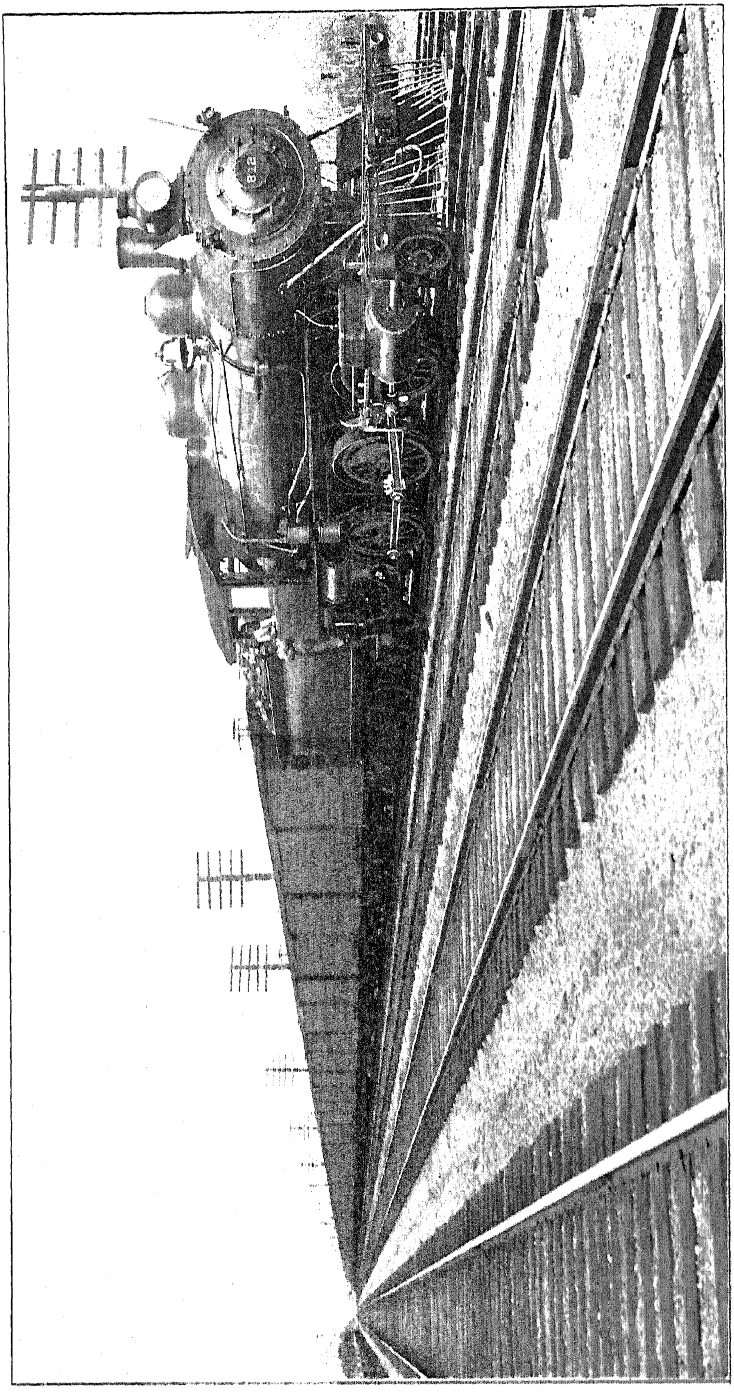
E. H. MILLER, New York City: What is the rule employed by the N. Y. Central Co. in determining the weight of rails? In other words, if such good results are secured with heavy rails, why do they stop at 100 pounds per yard? Why not take 120 or 150 pounds?

DR. DUDLEY: The stresses in the 100-pound rails are much smaller than they are in 80-pound rails; and the former are answering the demands of service very well, and will probably do so for a long time to come. A heavier rail of high grade would be very difficult for mills to roll. On the Boston and Albany Railroad I think 120-pound rails will be tried within a few years. The great difficulty as to heavier sections is to get them rolled by the mills. I believe 105 or 107 pounds per yard is the heaviest rail now rolled abroad.

MR. KENT: Would it not be advisable to plane the tops of the rails, and thus give a perfect surface?

DR. DUDLEY: Undoubtedly, rails should be more smoothly finished than they are. This would remove many of the surface-undulations and the consequent shocks now received by the wheels. In my paper I have spoken of the high stresses due to the roughness of the 80-pound rails described. They were full of waves, and gave much higher stresses than those of later manufacture.

FIG. 1.



N. Y. C. & H. R. Railroad Standard Grain-Train.

JOHN FRITZ, Bethlehem, Pa.: Dr. Dudley has said that the extra price charged by the mills for higher-carbon rails was $2 per ton. Speaking for the manufacturers, I do not wish to have it supposed that the extra carbon cost all that. The additional cost was due to the different material which we had to use, to carry the specified high proportion of carbon, without making the rails brittle.

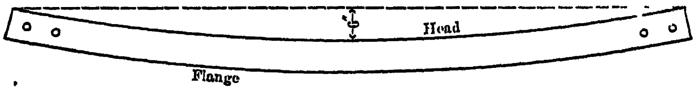
Dr. Dudley, with his severe requirements, has caused American rail-makers a great deal of trouble. But apart from that, he is on the right road, in using higher carbon, as the rail is stronger, will wear longer, and be easier on the road-bed. We have to consider not only the rail, but the locomotive and the road-bed. The rails have been charged with a good deal that is due to other elements in the problem. I believe that with a perfectly flat, straight, smooth and true rail, and perfect wheels, and a perfect road-bed, and one other thing which I will presently name, our present railway-speeds could be increased with safety. The final element to which I have referred is the elimination of the effect of the improper counter-balancing of locomotives, which seems to be inseparable from the use of steam. Electric locomotives do not need it; and if these should ever come into general use, it can be safely predicted that not only higher speeds, but much longer wear of rails, will result. I wish Dr. Dudley would give us his opinion as to the effect on the track of the counter-balanced locomotive wheels.

DR. DUDLEY: It is very serious on the rails and permanent way. The effect of the counter-balancing of the locomotive cannot be as closely calculated as that of a stationary engine; but it can be improved. It has been recommended that the counter-balance be put much closer to the hub of the locomotive-wheel, in which case it would not rise and fall so far, and would be easier on the track.

MR. FRITZ: It is the effect on the rails which concerns me. I have had a lot of trouble with it, and I speak feelingly from my past experience as a rail-manufacturer. On certain roads, where high speed was maintained, the bending of rails was very great; but the rails were not to blame. I wonder how the engines kept on the track at high speeds in the absence of proper counter-balancing. I remember one road, on which

there was a tangent of about 15 miles, which was always selected for fast running to make up lost time. That was the only part of the road on which they had trouble from the bending of rails; and the trouble there was very serious. Of course the rails were blamed first; but after they had reduced the speed permitted on that tangent, the cause of complaint disappeared. This incident illustrates the effect upon the track of a badly-balanced locomotive, running at high speed.

FIG. 2.



Rail Bent by the Locomotive.

In this instance, when the rails were taken out of the track and laid down free on the flange, the ends were 6 or 8 inches above the center, as shown in Fig. 2. They were also out of line sidewise some 3 or 4 inches, in the direction indicated by the line through the section in Fig. 3. This was caused by the surging of the locomotive against the inside of the rail. When the rails had been taken out of the track and were lying loose on the ground, it was impossible to put them in the track

FIG. 3.

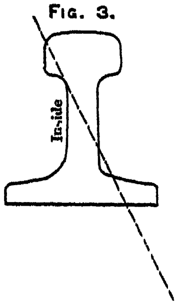


Diagram Showing Side-Thrust on the Rail from the Locomotive.

again in such a manner as to permit a train to pass over them in safety, at any reasonable speed. This condition of affairs was unquestionably brought about by what is generally called "hammer-pound," caused by the locomotive being out of balance. When new rails of the same carbon, pattern and weight were put in the track and the speed was reduced, the trouble ceased. In my judgment, to balance perfectly a loco-

motive of the present form is one of the most difficult of mechanical engineering problems; yet I hope to see it in some way accomplished. The locomotive will be much easier on the rails and road-bed, and it will be less difficult to keep the track in good order, and the engine will run more smoothly—all of which will tend to greater safety and increased speed.

The heavier and higher rails now coming into general use modify to some extent the effect to which I have referred, but the evil still exists.

ALLAN STIRLING, New York City: The subject of smooth or rough rails may receive some incidental illustration from the experience of the elevated railroads in New York City. When they began to be operated, the noise from the rails was terrible—so bad that I, as the superintendent, was called before the Grand Jury to answer the charge of maintaining a nuisance, and narrowly escaped an indictment for that offence. Those who resided here at that time must remember the extraordinary noise produced by our trains in passing over the elevated structure. But this noise gradually subsided; and we got in many quarters the reputation of public benefactors, for having skillfully abated the nuisance; whereas, in fact, the amelioration was largely due to the smoothing of wheels and rails by use. Our rails were rough when new, and so were our wheels (though they were steel-tired Allen wheels); but the effect of daily wear upon both was a marked improvement in this respect.

The International Correspondence Schools.

Secretary's Note on the Paper of H. H. Stock. (See *Trans.*, xxviii., 746.)

IN the footnote on the first page of Prof. Stock's paper, as printed in vol. xxviii. of the *Transactions*, I alluded to him, under an erroneous impression, for which he was in no way responsible, as "the present Director of the Scranton Schools." This incorrect statement placed him in a false position, as possibly having authorized the use of a title to which he had no claim. In fact, Prof. Stock has never had any official connec-

tion with the International Correspondence Schools. He is one of the editors of *Mines and Minerals*, a technical journal published in Scranton, and owned by the company which owns also the Correspondence Schools; but the two enterprises are separate and independent. I regret that, by ignorantly confounding them, I may have misled Prof. Stoek's readers concerning his exact relations to the subject of his paper.

R. W. R.

Correspondence Schools.

Discussion of the Paper of R. P. Rothwell, New York City. (See p. 338.)

H. H. STOEK, Scranton, Pa. (communication to the Secretary): Mr. Rothwell's condemnation of my paper on the International Correspondence Schools as not giving an impartial view of the whole field of such enterprises, because it was confined to the description of a single one, might be legitimate if I had undertaken or professed to do anything else than that which I was requested by the Secretary of the Institute to do—namely, to give an account of this particular institution. This is a sufficient answer to all his direct or implied criticisms upon my omission to mention either persons or organizations outside of the special limits set for me.

Recognizing fully that personalities have no place whatever in the *Transactions*, I regret the necessity of making the following statement in answer to Mr. Rothwell's charge that I omitted to give due credit to Mr. Ewald, a former principal of the International Correspondence Schools. The *Colliery Engineer* School of Mines was started in 1891, and its first student was enrolled October 16, 1891. During the fall of the same year the mine-mechanical course was laid out along the same general line that had already been followed in the mining course. This mine-mechanical course was the foundation from which sprung the later developments of the several mechanical courses.

The latest circulars of information of the International Correspondence Schools give the following as their distinctive features: (1) courses of instruction for particular occupations,

in which only such processes, facts and principles are taught as are necessary to qualify the student therein; (2) printed text-books and accompanying question-papers and drawing-plates, prepared expressly for each course; (3) thorough examination and correction of the written work of the student, and full, clear and exact written explanations of all difficulties met with in studying; (4) instruction suited to the requirements of all persons who for any reason cannot attend technical schools or colleges.

In the early circulars of information of these schools and in the pages of the *Colliery Engineer*, prior to April, 1892, when Mr. Ewald entered the employ of the company, these distinctive features were brought out, though perhaps not in the precise words above used; and, notwithstanding the growth of these schools during the past eight years, the general method of instruction, as formulated prior to April, 1892, is adhered to at the present time with remarkable closeness.

Mr. Ewald was first employed by the Colliery Engineer Company, April 30, 1892. He was made principal of the School of Mechanics in 1893, principal of the International Correspondence Schools in 1895, and remained in the latter position until March 31, 1897. He could not, therefore, have been, as claimed by Mr. Rothwell, the pioneer in these schools, since two, at least, of their courses had been planned, advertised,* and put into operation before he entered the employ of the company. Further controversy on this purely personal matter I must decline to pursue here; but I may be permitted to say that I do not know Mr. Ewald, having never even met him; that my omission to mention him in my paper was not an attack upon him; and that I do not feel that I should be here drawn by a third party into an irrelevant controversy about him, which I did not initiate, and which would doubtless be as distasteful to him as to me.

The organization, capitalization and financial management of the International Correspondence Schools are matters con-

* See, besides numerous announcements in the *Colliery Engineer*, the advertisement of "The Colliery Engineer School of Mines, a System of Instruction by Correspondence," printed in Mr. Rothwell's *Engineering and Mining Journal*, March 26, 1892, in which the courses in mining and in mechanical drawing are separately mentioned.

cerning only the stockholders of the company (of whom 23 are members of this Institute, while, besides these, more than 30 are managers of some of the best-known mining companies in America), who have unanimously approved every step of its business management, and who have access at all times to its books, besides regularly receiving statements of its business condition.

Mr. Rothwell has offered sundry criticisms which, though not openly directed against the International Correspondence Schools, convey strong condemnation of certain features in the system pursued by them. The question whether any such feature is (to quote Mr. Rothwell's phase) "to be disapproved" is a legitimate one for discussion here; and I, therefore, offer a few remarks on questions of this class.

1. As to the use of bound volumes of the instruction-papers, I would say that this practice was begun by the International Correspondence Schools in direct response to the request of students who had finished their courses, or were well advanced therein, and who desired to possess their instruction-papers in permanent form. When I say that these bound volumes and the instruction-papers are kept much more closely "up to date" than ordinary text-books, and that they are constantly subject to revision, I mean precisely what is meant by "revision;" and I do not mean that the words "New Edition" are printed upon the title-pages of volumes printed from old plates.

2. As to the furnishing of "keys," I would say that this is done by the International Correspondence Schools with certain precautions. That such "keys" may be improperly used is recognized, and that the students in these schools are distinctly warned against their abuse is shown by the following quotation from the circular sent to each student:

"To aid students who live at such great distance from Scranton that the time occupied in sending for and receiving special instruction is unreasonably long, and others who, for want of time or other reasons, cannot communicate with the Schools as often as is necessary, and would otherwise make slow progress, we have prepared keys for the question-papers in nearly all of the subjects in the courses we teach.

"The bound volumes of our different courses contain all the keys that have been prepared for these courses; but students who do not possess the bound volumes, or who are enrolled in courses for which the bound volumes are not yet ready, or do not wish to soil their bound volumes, can secure the keys in pamphlet form one at a time, as they may need them in connection with their work.

"The keys are not furnished with the instruction- and question-papers as part of the regular courses, as it is not intended that they should be used, except by those who cannot conveniently communicate with the Schools as often as may be necessary in order that they may make satisfactory progress in their studies; but if the keys are employed judiciously they can be made to save time without injury to the student

"The way to use the keys is to refer to them only when you feel you cannot master the problems in hand. Even then they should, except in rare cases, be used only to enable you to understand the step in the solution which you cannot grasp. They should not be used to copy your lessons from. They are merely intended for service in those emergencies when you feel that you must have help on some point, and do not wish to wait until you can write to and receive a letter from us regarding it If you use the keys, you will do well to bear these directions in mind, for unless you are well grounded in each subject, you will have difficulty in passing your final examination to secure your diploma.

"The keys are not a necessity, but merely a convenience for the classes of students mentioned, as all the information they contain will be furnished to the students free of charge, from time to time, if they write for it."

It is perhaps unnecessary to call attention to the fact that nearly every text-book extensively used in schools or colleges has its "key," or to the fact that many well-known educators advocate the judicious use of "keys" even in the instruction of students who come into daily contact with the teacher. This raises a profound question in pedagogy, which it is not necessary to discuss here. It will be sufficient to say that, of the students, scattered throughout the United States and more than 100 foreign countries, who have been, up to the present time (August 1, 1899), on the roll of the International Correspondence Schools, the number in Mexico, Great Britain, Canada, India, South Africa, the Philippines and Oceanica, has been 5600. If these students had been compelled to depend upon the mails for the explanation of every difficulty they might encounter, their courses would have been unduly prolonged, and they would have been correspondingly discouraged.

I gave in my paper, as one of the reasons for the success of correspondence instruction, "the character of the students, who are not school boys, but men who are spending their own hard-earned savings, and who have the foundation of practical experience, upon which to base the theoretical superstructure." To such students, it is not considered necessary to apply rigorously the methods of a primary school. No doubt, training in simple honesty is fundamental; and it is injurious both to the character and the real progress of a student to use secretly

the assistance, either of a friend, or a "key," or a "pony," in attaining a result which he professes to have reached by his own unaided labor. Yet, as I have said, many of our best educators advocate the judicious and open use of "keys," as eliminating a vast amount of really useless labor on the part of an honest student, and innumerable standard text-books have their "keys." This does not imply that educators are indifferent to honesty in their students, but rather that they have other ways of testing that quality than the mere inspection of a "correct answer."

In correspondence-instruction we have, on the one hand, the special safeguard already mentioned, in the presumable character and purpose of the student, and, on the other hand, the undeniable possibility that, if the student desires to cheat, he can do so, up to a certain point. For instance, he might, perhaps, copy directly from his instruction-paper the answers to some of the questions in the corresponding question-paper, though this is rendered difficult, if not impossible, by the careful wording of both. In like manner he might misuse the "keys;" but, as will be seen in the circular above quoted, his attention is distinctly called to the danger of such abuse, and he is warned that if it be persisted in he will certainly "come to grief" in his final examination, even though he may not have been detected during his course. I need scarcely say that to this final examination there is no "key;" and, unless a student can pass it satisfactorily, no matter what his previous record may have been, his certificate is refused, and he is compelled to go again over the subjects in which he had been found deficient. So far as the International Correspondence Schools are concerned, I am, after laborious inquiry, unable to find a single instance in which a diploma has been finally granted to a person who had not honestly earned it.

3. Mr. Rothwell criticises me for dignifying with the title of "instructors" young women who make the preliminary examination of the work returned by students. I am at a loss to know what other classification would have obviated Mr. Rothwell's objection; but I welcome this opportunity to say that the young women who make preliminary examinations of papers received from students are graduates of high schools, normal schools, and institutions of like grade, and that before

any one of them is permitted to do this work she must pass an examination in arithmetic, algebra, logarithms, geometry, trigonometry and physics. She is then permitted to correct only the most elementary arithmetical papers, and is advanced to higher work only upon proof of ability therefor. In no case is anyone permitted to undertake the examination of more advanced papers without having passed an examination upon the same under the supervision of the principal of the department concerned. The same system is pursued in the course in mechanical drawing; and I will say, without fear of contradiction, that the drafting done by these young women, in qualifying themselves for responsible duties in that department, is better than the average work done in American technical schools.

Note on the Disintegration of an Alloy of Nickel and Aluminum.

Discussion of the Note of Erwin S. Sperry, Bridgeport, Conn. (See p. 280.)

ALFRED E. HUNT, Pittsburgh, Pa. (communication to the Secretary): My experience has been similar to that described by Mr. Sperry, regarding a 50 per cent. alloy of nickel and aluminum. Moreover, the same phenomena occur with a 50 per cent. alloy of iron and aluminum, manganese and aluminum, chromium and aluminum, or tin and aluminum. It seems that there is a narrow limit of composition of these metals, within which, when they are alloyed, they crumble down into a powder after standing for any considerable time. The resulting powder does not seem to be a separation or disintegration into the elements composing the alloy, but simply a powdering down of the alloy itself.

The physical properties and utility of any of these alloys in powdered form have not been carefully investigated as yet, and offer a field worthy of further investigation.

SAMUEL PETERS, Pittsburgh, Pa. (communication to the Secretary): In the early seventies, during the early days of the open-hearth process in this country, the writer was engaged as

chemist to the Bay State Iron Co. of South Boston, Mass., under the superintendence of the late Ralph Crooker. It was our practice then to make our own ferro-manganese, which we did by adding franklinite, containing about 12 per cent. of manganese, to plumbago crucibles containing oxide of manganese mixed with charcoal, and melting down the contents. We thus easily obtained alloys containing 30 per cent. of manganese.

Later, to get richer alloys, we omitted the franklinite and obtained alloys containing about 80 to 85 per cent. of manganese, with a small amount of iron, but considerable combined carbon. On exposure to the atmosphere, we found that in the course of time the rich alloy disintegrated completely to a fine powder. During the disintegration the well-known odor proceeding from hydro-carbons was noticed. The powder apparently consisted of the mixed oxides of manganese and iron. It was evident to me that the whole mass was oxidized through the agency of moisture.

In Mr. Sperry's note he does not state whether or not he thinks the alloys, when disintegrated, were in the elemental state or whether they had been converted into their oxides. If they were in the latter state, it would be interesting to know whether he would find the same result to be obtained if means were taken to exclude moisture.

It is almost needless to remark that when ferro-manganese was made in crucibles, the price obtained for open-hearth metal was many times greater than it is to-day.

The Equipment of Camps and Expeditions.

Discussion of the Paper of Prof. Charles H. Snow, New York City. (See p. 157.)

SECRETARY'S NOTE.—On page 176 of this paper, in the fourth line of the first footnote, "4°" should be "1°": and on page 180, at the beginning of line 23, "lined boot" should be "unlined boot."

DISCUSSION.

FRANK OWEN, London, Eng. (communication to the Secretary): In his very interesting and valuable paper, Prof. Snow

says he fails to find that any attempt has yet been made to collate and compare the experiences of engineers in the important department of which he treats. Agreeing with him that the literature directly dealing with this subject is not voluminous (though many incidental discussions of it may be found in the books of travelers and the reports of explorers), I may fairly say that the field is not altogether barren, and claim for British authors the credit of some early and valuable contributions.

The Royal Geographical Society first issued in 1854 its "Hints to Travelers," a work which reached in 1893 its 7th edition. The chapters devoted to "Outfit" and "Surveying" are eminently worthy of attention; and there are also valuable notes on the preservation of health in the tropics, furnished by the late Surgeon-Major Parke, who was attached to the Emin Pasha relief expedition in Africa.

I may mention also a useful paper on "The Equipment of Exploring Expeditions," by Mr. M. Walton Brown, which was published in the *Transactions* of the Institution of Mining Engineers (Newcastle, Eng., vol. xv., Part 4, August, 1898).

These citations of earlier publications on the subject do not in the least detract from the original merit or the timely value of Prof. Snow's fresh and comprehensive treatment of it.

The Discovery of New Gold Districts.

Discussion of the Paper of H. M. Chance, Philadelphia, Pa. (See p. 224.)

FRANK CLEMES SMITH, Deadwood, S. D. (communication to the Secretary): The reading of Mr. Chance's interesting paper suggests a few ideas relative to his discussion of certain Black Hills gold-ores.

Mr. Chance refers to his examination, in 1897, of "the (Carboniferous) limestone plateau-country which encircles the central area of the Black Hills," and says that "it had been generally assumed that the mineralization of this formation was confined to the northern area;" further, that he "found, however, a general mineralization, extending in zones or belts throughout the region," and that the ores, being more or less specially

silicified, contained gold in quantities ranging from \$1 to \$5 per ton.

While the report of the occurrence of siliceous gold-ores, of something like the above gold-content, more or less remote from the northern area, is doubtless of value, in that it may serve to encourage further prospecting of such areas, the fact should not be overlooked that siliceous gold-ores of that grade cannot, at present, be properly called "ores" in the Black Hills, since they have no economic value whatever. Under the best of conditions as to cost of mining and treatment (in the mining company's own reduction works), it is probable that under the present metallurgical conditions, siliceous ores must carry from \$6.50 to \$7.50 per ton before they would even pay expenses, and, in the case of the shipment of such ores to a custom-works, their gold-content must reach the neighborhood of \$12 per ton before they would pay expenses.

Shortly after the discovery of the Ragged Top ores, some three years ago, vast numbers of samples, from every limestone area in the Hills, poured into the various assay-offices. Many of these samples, sent to the School of Mines, came under the observation of the writer, and bore a strong resemblance to the siliceous ores of Ragged Top, but in no single case of which I am aware did any such sample, coming from any other than the "northern" area, show any economic value or lead to the discovery of any workable deposit.

It is a well-known fact that a vast number of various rocks in the Black Hills, from certain silicified rocks of the Cretaceous, Jura-Trias, Carboniferous and Cambrian to those of the underlying Archean, carry gold in small quantities, say, from 50 cents to \$2 per ton. In the Archean the number of different auriferous schistose rocks is bewildering, while almost any pyritous body or ferruginous seam carries a small amount of gold. The degradation of the auriferous Archean rocks doubtless formerly supplied the gold in the [illegible] quartzites of the Cambrian, which, throughout the entire circle of the Hills, almost universally carry that metal in small quantities. In the latter formation, at various places in the southern hills, there are notable deposits of valuable hematite-ores which are slightly auriferous.

The accepted assumption that the mineralization of the Car-

boniferous (and also of the Cambrian) measures is confined to the northern area, is due to the fact that only in that area has the most persistent prospecting opened any deposits of economic value; and since the northern area only is characterized by later igneous phenomena, it is to these phenomena that the economically important mineralization is ascribed.

Referring to the siliceous ores of Ragged Top, Mr. Chance suggests that their gold may exist in some unknown condition, in, or combined with, a siliceous matrix, and that, although the presence of tellurium has been reported, the assumption that the gold exists as a telluride is rendered improbable by the failure to find tellurium minerals, and by the failure of the most careful tests with a very rich ore to get any heavy concentrates carrying more than $10 per ton.

Admitting the presence of tellurium in these ores, in the absence of all other metals beside silica, a little iron (not pyrite), alumina and lime, with gold and silver, it would seem unwise to predicate the existence of the gold in some unknown condition, rather than as a telluride, upon such negative evidence, especially since tellurium minerals *do* exist in this very neighborhood—a fact which doubtless escaped Mr. Chance's observation. In the ores of the Ironsides mine, near Squaw Creek, sylvanite can be frequently seen in thin films in seams in the rock. In cases where water has penetrated these seams, the metallic gold remains, presenting the appearance of a thin scale of minute grains.

A microscopic slide was made from a piece of this ore by Professor J. F. Kemp of Columbia University, who pronounced it an orthoclase-porphyry. That the mineral sylvanite occurs in ores of the immediate vicinity of the Ragged Top deposits, even though the ore be an igneous rock belonging to one of the dikes which everywhere cut the sedimentaries of this region, and not a metamorphic rock such as the Ragged Top ore, is a fact which seems to lend some probability to the existence of the gold as a telluride in the Ragged Top ores themselves. The fact that neither the gold nor any telluride minerals can be seen in the Ragged Top ores with the naked eye is probably due to the very thorough distribution of the mineral containing the gold in minute particles throughout the ore.

With regard to the concentration of telluride-ores, I will

refer to the results obtained at the Huronian mine in Ontario,* where, after amalgamation in stamp-batteries and upon plates, 69.1 per cent. of the ore-values was lost; 29.3 per cent. of the total value being recovered in the form of coarse concentrates upon Frue vanners. From the well-known sectility of tellurides, combined with the very fine crushing necessary for the tough high-silica Ragged Top ores, it is scarcely likely that any heavy concentrates could be obtained, but more probable that the tellurides would pass off as slimes.

Tests of these ores, roasted and unroasted, have been made by the writer† with a very material variation in the results of the assays of the roasted and unroasted sample. These tests have been confirmed by the work of Mr. Sleightholm Barker, who is at present connected with the School of Mines at Rapid City. In making such tests it is not even necessary that the precious metals should exist in chemical combination with tellurium; the mere presence of metallic tellurium as a mixture with the ore being sufficient to cause loss by volatilization and cupel-absorption.

In the paper first referred to above, mention is made of certain ore-samples from the Huronian mine which resembled pieces of ordinary smoky quartz, and in which, even upon crushing, no metallic grains could be found, but which yielded upon assay as high a value as 902 ounces of silver and 34 ounces of gold per ton, the precious metals undoubtedly existing in these samples, as in all of the ore from the mine, as tellurides. A similar condition might easily be possible in the low-grade ores of Ragged Top, the slight color or smokiness being absent in the latter as a function of their much smaller precious-metal content.

The writer is not prepared to question the possible existence of gold in unknown combinations, or possibly as a silicate; the well-known affinity of gold for silica, as evidenced by its frequent occurrence in quartz-veins, has long led the prospector to neglect the possibility of its occurrence in wall-rocks of various kinds; indeed, it may be said to have given indirectly occasion for Mr. Chance's valuable article.

While on this subject, and with reference to the very thorough

* *Trans.*, xviii., 439 *et seq.*

† *Trans.*, xxvi., 194.

distribution of the mineral containing the gold throughout the ores of the Ragged Top region, as well as the earlier-known ores of Bald Mountain and Ruby Basin, I wish to consider briefly the question of their assay, referring to Mr. Furman's discussion of my paper on "The Occurrence and Behavior of Tellurium in Gold-Ores."*

In that paper, a table given on page 491, containing the results of assays of portions of two ores crushed to different degrees of fineness, shows conclusively a very even distribution of the precious metals throughout the ores. Such being the case, a finer crushing than 60-mesh as a preliminary to assay would be simply superfluous. Mr. Furman says that "all of us here in Colorado who have had anything to do with the assay of tellurium-ores (and we have had a good deal in the last three or four years) know that a sample crushed through a 60-mesh screen cannot represent the ore from which it was taken." With due consideration for Mr. Furman's long experience with Colorado telluride-ores, it would seem advisable that his statement above should have been qualified by confining it to the assay *of Colorado ores*. Later on he describes the Cripple Creek ores as "a mass far from uniform in composition." This condition not prevailing with the siliceous ores of the Black Hills, Mr. Furman's conclusion (that assay-samples should be taken only after crushing to 100-mesh) does not apply.

H. M. Chance (communication to the Secretary): I have read Professor Smith's discussion of my paper on the discovery of new gold districts with much interest; and the occurrences cited by him regarding the peculiarities of certain ores, containing gold in some of its various forms of combination with tellurium, constitute valuable additions to our knowledge in this direction.

There are only one or two points upon which I desire to comment, and these cover issues upon which I think Professor Smith rather misinterprets some of the statements made in my paper. I refer particularly to his comments on those mineralized areas in the southern part of the Black Hills, in the carboniferous limestone formation, in which he calls attention to

* *Trans.*, xxvi., 485 and 1106.

the commercial difference or distinction to be made between "ores" and rock of no commercial value, and points out the fact that siliceous ores must carry from $6.50 to $7.50 per ton in order to pay the expenses of working, and that they must have a value of $12.00 per ton to pay shipment and treatment charges at a custom-works. Every one familiar with the conditions in the Black Hills country is aware of this fact; but from a mineralogical standpoint, considering broadly the question of the limits of mineralized territory, it seems a matter of no import whether the mineralization ranges from $2 to $5 per ton, or reaches the higher figures necessary for the development of a profitable mining industry.

As before stated, we have in these southern hills vertical fissures in the limestone, containing in some cases a siliceous matrix almost identical in appearance and characteristics with the Ragged Top ores, but containing not more than from $2 to $6 per ton in gold; and, further, we find some of the sandy beds of limestone altered by infiltration of silica, and in many such cases this sandstone, or sandy lime, shows assay-values of from $3 to $5 per ton. We have here, undoubtedly, conditions of mineralization similar in every respect to those of the northern hills, but the gold-values are too low for profitable treatment with present metallurgical processes. The perfection of some new process can readily be conceived as bringing these low-grade ores within the class of commercially profitable ores, in which case the distinction made by Professor Smith would disappear.

In the northern hills the occurrence of what Professor Smith terms "later igneous phenomena" may perhaps be given undue importance by those who associate these "igneous phenomena" with the mineralization, as it has never been demonstrated that the "igneous phenomena" closely associated with mineralized areas is *later* than similar disturbances farther south; but even granting that this had been demonstrated, there yet remains to be demonstrated the connection between these "later phenomena" and the mineralization. The mere occurrence of mineralization and "igneous phenomena" in a certain region does not necessarily demonstrate that their relation, one to another, is that of cause and effect.

The writer is pleased to note that Professor Smith is not

prepared to question the possible existence of gold in unknown combinations, or possibly as a silicate; and it is his desire to restate carefully the position already taken as being one merely suggesting the possible occurrence of gold in some such form of combination, as a constituent of what might be termed rock or gangue of low specific gravity, as such a combination would explain many of the difficulties which he has personally experienced.

The writer has further, since making the above communication to the Institute, had a number of communications, oral and written, from assayers and metallurgists, describing difficulties and similar experiences which cannot be explained by the assumption advanced by Professor Smith that finely divided tellurium-gold compounds pass away as slimes. It is readily conceded that, under such conditions, concentration is not feasible as a commercial method of recovering values; but it does not seem possible to conceive the existence of any mineral of high specific gravity escaping *entirely* from the pan, in making a careful pan-test. The instance quoted by Professor Smith of the "smoky quartz" ore from the Huronian mine may possibly be an instance of just such a combination of gold with silica as has been suggested. The value of this instance, which Professor Smith quotes in support of the theory that the gold exists in this smoky quartz in the form of telluride, would be much enhanced if he would add to the statements of ore-value (902 ounces of silver to 34 ounces of gold per ton), the quantity of tellurium which this particular sample of smoky quartz contained. Without this information, the data submitted appear incomplete, and the deductions therefrom inconclusive.

The writer hopes shortly to submit to the Institute a compilation of opinions gathered from a number of assayers and metallurgists, as above noted, upon this subject. One of the gentlemen referred to, whom I have not had the opportunity of consulting, and therefore do not wish to name, has recently, in a letter, written, however, before having seen my communication to the Institute, expressed an opinion almost exactly tallying with the suggestions outlined. He states that he has arrived at the conclusions purely from circumstantial evidence, but he regards this circumstantial evidence as very strong, and almost, if not quite conclusive, and that he was led to believe in the

existence of possibly double or triple silicates of gold, with other metals.

RUFUS BUCK, Dawson, Klondike, N. W. Terr., Canada (communication to the Secretary): Dr. Chance is in error in his statement (p. 224) concerning the Klondike discovery. It was Robert Henderson who, with three companions, discovered, by systematic prospecting, the Klondike "diggin's." Carmac, the "poor fisherman" to whom Dr. Chance refers, was invited by Henderson to come in and stake a claim, but wished to stake claims for his Indian brothers also. Against this, Henderson protested; and Carmac and the Indians consequently crossed the divide into Rabbit Creek, now known as Bonanza, where they prospected, and discovered gold.

H. VAN F. FURMAN, Denver, Colo. (communication to the Secretary): Mr. Frank Clemes Smith, in his discussion of Mr. Chance's paper,* takes exception to some remarks made by me in discussion of his own paper entitled "Occurrence and Behavior of Tellurium in Gold-Ores."†

While I have had but a limited experience with the gold-ores of the Black Hills, my experience with gold-ores in general, which comprises ores from many parts of the world, leads me to adhere to my original statement. I have asked several of our local assayers, both commercial and smelting-works assayers, for their opinion on this subject. Some of these men have had experience with the ores of the Black Hills district, considerable quantities of these ores having been shipped to Denver for treatment. They all confirm my original statement, that the assay-sample should be put through a 100-mesh sieve. Many of them insist upon the adoption of a 120-mesh sieve, which I believe to be a step in the right direction. Personally, I should hesitate to purchase a lot of gold- or silver-ore upon the assay-results of a sample crushed to pass a 60-mesh sieve. Although the "bucking" of the assay-sample to 120-mesh size involves additional time and labor, the time and labor thus expended is not great; and anything which tends towards greater accuracy, without necessitating excessive and useless expense, is most certainly advisable.

This question of the proper preparation of samples of gold-

* *Ante*, p. 1035.

† *Trans.*, xxvi., 485.

and silver-ores for assay, and the assay of such samples, is of great importance, and, in my judgment, worthy of a thorough discussion by members of the Institute.

Plate-Amalgamation.

Discussion of the Note presented by Allan J. Clark, Lead, South Dakota.
(See p. 459.)

George E. Collins, Nacoochee, Ga. (communication to the Secretary): The results tabulated below were obtained at the Reynolds mill, White county, Ga. They were noted, not with a view to investigating the point discussed by Mr. Clark, but in course of a test on a working scale to determine the comparative saving from a given free-milling ore on copper and silvered plates respectively. In every case the bullion assayed was the result of a separate clean-up on a considerable quantity of ore. The ore varied widely in grade and in other respects, but the runs bracketed in the table were made at the same time, in adjoining batteries, and on similar types of ore. In a

Month.	Plate.	Fineness of Bullion.		Ratio, Gold to Silver.
		Gold.	Silver.	
December, 1898	Silver-plated.	819	141	5.81 to 1
	" "	769	181	4.25 to 1
	Copper.	884	99	8.93 to 1
January, 1899	Silver-plated	775	108	7.18 to 1
	Copper	855	117†	7.31 to 1
February, 1899	Silver plated.	720	143	5.04 to 1
	Copper.	822	67	12.27 to 1
February, 1899 (same ore)	Silver-plated.	639	151	4.23 to 1
	Copper.	619	82	7.55 to 1
March, 1899 (same ore)	Silver-plated.	798	107	7.46 to 1
	Copper.	732	72	10.17 to 1
March, 1899 (same ore)	Silver-plated.	801	180	4.45 to 1
	Copper.	770	207†	3.72 to 1
April, 1899 (same ore)	Silver plated	821	162	5.07 to 1
	Copper.	867	127	6.82 to 1
April, 1899	Silver plated.	808	188	4.30 to 1
	" "	852	144	5.92 to 1
	Copper.	754*	91	8.29 to 1
April, 1899	Silver-plated.	859	117	7.34 to 1
	Copper.	892	90	9.91 to 1

* Result modified by the addition to the bullion-shipment of a little impure bullion left over from previous clean-ups.

† On these occasions, the strips of copper were removed from the tables, and their lower surfaces were cleaned. Hence the higher yield reported.

few cases (so noted) the ore was specially mixed, fed from the same bin, and for practical purposes identical. The assays are quoted from the certificates of the United States Assay office, Charlotte, N. C., to which the retorted bullion was shipped.

It will be seen that the fineness of the bullion obtained, both as to gold and silver, showed extraordinary variations, due presumably to changes in the ore; but that as a general rule the silver ratio of that from the battery provided with the silvered plate was decidedly higher. At first sight these results fit in with the theory suggested by Mr. Clark, that there is a tendency for the silver in the pulp to resist amalgamation on an amalgamated copper plate, as compared with a silvered plate.

The figures, however, do not tell the whole story. The mortars in the Reynolds mill are similar to the "Hall" type (described and figured by Nitze and Wilkens* in their paper on "Gold Mining in the Southern Appalachian States") but designed for 750-pound instead of 450-pound stamps. Most of the amalgam is really collected in the mortar-box, around and behind the liners, and is only flushed out on the plates in the course of the clean-up. The proportion originally deposited in the mortars varies, of course, as the gold in the ore is finer or coarser, but will be from 40 to 85 per cent. of the total. If, therefore, we confine our attention to the amalgam deposited on the plates in the first instance, the difference in fineness will appear so great that we can hardly ascribe it altogether to a greater affinity of the silver in the pulp for the silver-plated surface.

Every millman knows that the silver on an electro-plated plate tends to wear off in course of time, especially when low-grade ore is run over it; and this loss of silver may continue indefinitely, on a small scale. Similarly, at custom-mills it is often found that ore, however barren, run over a copper plate which has become well coated, will abstract some of the amalgam from its surface. At Black Hawk, Colo., there is (or was) a trick among unscrupulous ore-haulers out of a job, of bringing in worthless ore from some convenient dump and hauling it in small lots to different mills, in the hope that one or other of the

* *Trans.*, xxv., 745, 1895.

loads would be run over a plate in direct succession to a lot of rich ore, and so would yield something at the expense of the mill's *bonâ fide* customers.

The loss of silver was plainly noticeable on the surface of the plate at the Reynolds mill. Up to May, 1899, when the above-noted tests terminated, about 170 ounces of bullion had been removed from it, with an average silver assay, in the cases recorded, of 41-thousandths in excess of that from the copper plate; so that the total excess of silver only amounted to 6.97 ounces. May not this have been derived entirely from the plate? Its superficies is 37.33 square feet, originally plated with 1 ounce per square foot, or 37.33 ounces of silver in all. Surely it is not unreasonable to suppose that 18.7 per cent. of the total silver on the plate may have been removed with the amalgam in the course of several months. May not part or all of the effect observed by Mr. Clark at the Homestake be accounted for in the same way? The admission of this suggestion will, of course, not affect the general question as to decrease of gold fineness in bullion with increasing distance from the battery.

At the conclusion of the above-noted tests it was established that, notwithstanding the lower fineness of the bullion, the net saving on the silvered plate was in excess of that on the copper plate. The latter was replaced with a new silvered plate, and similar tests were then made on the old and new silvered plates, with the following results:

Ore.	Plate.	Fineness of Bullion.		Ratio, Gold to Silver.
		Gold.	Silver.	
Same ore	Old plate.	901	81	11.12 to 1
	New plate.	876	108	8.11 to 1
Same ore	Old plate.	905	87	10.40 to 1
	New plate.	893	101	8.84 to 1

As might have been expected, the bullion from the old plate (the most easily removable part of the plating on which had, no doubt, already been taken off with the amalgam) was considerably lower in silver than that from the new plate.

After the reading of Mr. Clark's paper, a third test was

made, in which the amalgam collected inside the mortars and that deposited on the plates were cleaned up and assayed separately. The following figures were obtained from a 65-hours' run, both batteries being fed with the same ore:

Battery A.—Fitted with old silvered plate.
Battery B.—Fitted with new silvered plate.

	Ounces Amalgam	Ounces Melted Bullion.	Fineness of Bullion.		Ratio, Gold to Silver.
			Gold.	Silver.	
A. Collected in mortar......	10.76	6.	900	91	9.89 to 1
A. Deposited on plate......	5.69	1.35	794	160	4.96 to 1
B. Collected in mortar......	12.21	6.98	933½	60	15.56 to 1
B. Deposited on plate.......	10.81	2.98	805	185	4.35 to 1

The relative quantities of amalgam and gold obtained from the two batteries must not be taken into consideration, as, owing to the breakage of a cam in battery A., the quantity of ore put through was unequal.

To some extent, this test corroborates the former results; the difference in fineness of the gold from the two mortars, fed with the same ore and under identical conditions, is, however, perplexing.

The writer questions whether the heavy silver-plating—2 or 3 ounces per square foot—sometimes adopted in gold-mills, is not a mistake, and whether it would not be more economical to use a thin coating—1 ounce or less—renewing it, if necessary, as the silver wears off.

H. Van F. Furman, Denver, Colo. (communication to the Secretary): In the papers and discussions on copper-plate amalgamation, and the accumulation of amalgam on copper plates, which have been presented to the Institute in the past few years, I have seen nothing regarding the efficiency of copper-alloys as amalgamating-surfaces. This is an extremely interesting subject; and I hope the few words which I have to say may be productive of discussion.

Dr. T. K. Rose says:*

"The use of Muntz metal (which consists of copper 60 per cent., zinc 40 per cent.) for amalgamated plates is of great interest. It differs from copper in catch-

* *The Metallurgy of Gold*, Chas. Griffin & Co., London, 3d edition, 1898, p. 133.

ing gold well as soon as the plate is amalgamated, not requiring to be covered with gold—or silver—amalgam before it begins to do good work. Moreover, the amalgamated surface is very superficial, since the mercury does not sink in so far as it does into a plate composed of pure copper, so that only a small quantity of mercury is required to cover it. The result is, that cleaning-up is easy and rapid, no iron instrument being necessary, but rubber being always sufficient. These properties make it particularly valuable for custom-mills, where it is desirable to catch as much as possible, without mixing the amalgam obtained from two parcels of ore crushed in succession. On the other hand, as it holds little mercury, it cannot absorb much gold, and must be cleaned up at frequent intervals.

"The mercury on Muntz-metal plates does not suffer so easily from 'sickening' as that on copper plates; it has been suggested that this is due to the electrolytic action of the copper-zinc couple, which sets free nascent hydrogen, and so reduces the compounds of mercury and other metals which have been formed. It follows that Muntz-metal plates are preferable for ores containing large amounts of heavy sulphides or arsenides. The greenish-yellow stains (called 'verdigris' by mill-men) which are formed on copper plates when grease and other impurities are present in the battery-water, do not appear when Muntz metal is used; and such discolorations as occur on these plates can be better removed by dilute sulphuric acid than by potassium cyanide. At the Saxon Mill, New Zealand, the copper plates formerly required 7 pounds of cyanide, costing 28s., per month to keep them in order, while the Muntz-metal plates, by which they were replaced, could be kept clean by 5 pounds of sulphuric acid per month, the cost being 3s. 4*d.* It is stated, however, that, in the treatment of highly acid ores, which have been weathered for some time, so that they contain large quantities of soluble sulphates, or in cases where the battery-water contains acids, copper plates are less affected than Muntz metal, over which a scum is rapidly formed. This is not the experience in Thames Valley, N. Z., where Muntz metal is preferred in spite of the extremely acid nature of the water and ore.

"Generally it may be stated that Muntz-metal plates are cheaper, wear better, and require less attention than copper. In dressing new Muntz-metal plates the following method is adopted in New Zealand: The surface of the plate is scoured with fine, clean sand; then it is rinsed with water, and washed with a dilute (1 to 6) solution of sulphuric acid. Mercury is then applied and rubbed in with a flannel mop, until it wets the surface of the plate (*i.e.*, amalgamates with it) in one or more places, after which the mop is given a circular movement, passing through these spots, until the amalgamation of the surface spreads from them over the whole plate.

"The discoloration of the Muntz-metal plates is prevented by the weak electric current produced, as has already been stated. The same effect can, according to Aaron, be obtained when ordinary copper plates are in use, by placing them in contact with iron or some other metal which is positive to copper. Strips of iron bolted to the top and sides of the plate are said to be sufficient for the purpose; the copper being in that case unaffected by the acidity of the water, which causes oxidation and dissolution of the iron only."

Dr. Rose adds that "Janin's experience does not support these views;" but my own personal experience with Muntz-metal plates leads me to indorse them. Any one who visits the stamp-mills of Gilpin and Clear Creek counties, Colo., or other localities where sulphide ores are treated by stamp-mill-

ing and plate-amalgamation, will notice the tendency of the plates to become discolored. Some three years ago, parties who were experimenting on the recovery of gold from the tailings discharged into Clear creek called my attention to this matter. I found that, even where the tailings and water were taken from the creek many miles below the mills, there was a marked tendency to discoloration of the plates after a few hours' use. The ordinary amalgamated copper plate became worthless as a gold-saver after about twenty-four hours. Silver-plated plates showed a somewhat longer life, but their efficiency in saving gold was soon destroyed by the acid waters. I tried Muntz metal; and the results, though not all that I had hoped for, were more satisfactory than any obtained with the ordinary plates. This led me to experiment with plates consisting of aluminum-copper alloys. I made three aluminum-copper alloys, containing respectively 5, 10 and 15 per cent. of aluminum, which were rolled into plates, amalgamated and subjected to various tests. I found that these plates, when immersed in the tailings and water from the creek, suffered practically no discoloration. I tried them also with water and freshly-broken pyrites; with water and pyrites which had long been subjected to atmospheric influences; and with water containing small amounts of free acids and free alkalies. In every case they showed practically no discoloration. The plates were examined with a magnifying glass, to see if the gold was readily caught by the amalgamated surface. The results were so satisfactory that I inquired of leading manufacturers of rolled copper whether they could make me a few plates of a copper-alloy containing 10 per cent. of aluminum. They replied that there was no market for such material, and that they could not undertake its manufacture.

Since that time I have had no opportunity to pursue this investigation; but I offer the above remarks, in the hope that they may stimulate further experiment or elicit additional information regarding this interesting subject.

Stoping with Machine-Drills.

Discussion of the Paper of B. L. Thane, Sumdum, Alaska. (See p. 770.)

VICTOR G. HILLS, Cripple Creek, Colo. (communication to the Secretary): In continuation of the subject of the performance of "baby machine-drills," presented by Mr. Thane, I submit the following records of work done with these drills in the Cripple Creek district of Colorado.

Two years ago, the Anchoria-Leland mine began to use baby-drills; and, to make the experiment more complete, began by purchasing two machines, of the same size, but of different make. The little drills were first used for stoping and upraising, in which they achieved at once an unqualified success. Soon after, they began to be used for the smaller branch-drifts and prospecting cross-cuts, while the large two-man drills were still used for the main drifts. Now they have almost entirely superseded the large drills, since it has been found that they will do any ordinary work in the mine at less cost, both for labor and for powder, per ton of rock broken. The large drills, of course, make more rapid progress; but it is only where time is a specially important factor that they are now used.

The Portland mine, where, until within a year, only the large machines were used, is now using some small drills for stoping, and also for drifting.

Mr. Thane speaks of having two men to operate a baby-drill; but in this district the baby-machine is always worked by one man without help. Again, in Prof. Christy's postscript, the quoted extract from a letter of Mr. L. T. Seymour, the South African engineer, mentions a "2¼-inch Little Giant," as though that were the smallest machine used in that region. These statements leave some doubt as to just what Mr. Thane means by a "baby-drill." To avoid any such uncertainty as to the present communication, I will say that the large or two-man drill in common use at Cripple Creek has a 3⅛-inch cylinder; while a few mines employ a 3-inch, and a few, in running large tunnels, a 3½-inch drill. What we call a baby-drill here has a

2-inch cylinder, and uses $\frac{7}{8}$-inch steel for "starters" and $\frac{3}{4}$-inch for the long drills. Such a machine will handle drills 8 feet long; but holes are usually from 4 to 5 feet, and seldom more than 6 feet deep.

In this district these drills are always used with a bar, are commonly spoken of as "one-man drills," and are operated strictly as such. That is to say, the machine-man has no help, either to set up or to run his drill; does his own loading and blasting, and has to shovel away his own waste sufficiently to make room for his next set-up.

It is with such a drill, thus operated, that the following records were made: Total length of holes drilled in one shift of 8 hours, 35 to 45 feet; average, 39 feet.

Of course, the amount of ore broken, or the length of level driven in a given time or at a given cost, depends on the thickness of vein or the size of headings, as well as the character of rock; and, therefore, the length of the drill-holes in a given rock is the only fair test of the efficiency of the drill. But some additional particulars may be interesting. A man driving a drift or cross-cut, 4 by 7 feet in section, puts in 9 to 12 holes for his shift's work. Records by the month, without any allowance for break-downs, sickness, holidays, etc., show an average of 4.3 feet to 4.7 feet per day with two shifts. A man frequently makes 3 feet a shift for many days in succession. In making an up-raise 4 feet wide by 8 feet long, a man averages 2 feet per shift, doing his own temporary timbering. Regular timbermen follow, 10 to 15 feet behind, providing a safe place to store the machine, hose, etc., at blasting-time.

Shaft-sinking with these little drills is illustrated by the following record: Size of shaft, 17.1 by 8.2 feet; depth of working, 900 to 1000 feet; no water. Two baby-drills sank the shaft 5 feet every two days; the machine-men working only $1\frac{1}{2}$ shifts in 48 hours, and an equal amount of time being required to remove the waste and put in a 5-foot set of timbers. Five "muckers," working one shift, are required to remove the waste. If any one knows of a record for cheaper sinking in a shaft of that size and depth, I should like to have it reported.

A company furnishing compressed air for general distribution in this district charges $2 per large drill per shift, where only a small number of drills are used. I understand that

there is a considerable discount to mines using a large number. By actual test at the Anchoria-Leland mine, we have found that a small compressor, which would just operate two $3\frac{1}{8}$-inch drills, will run five 2-inch drills. Coal costs from \$4.50 to \$6 per ton, according to quality.

From the above data, the cost of air for drills of different sizes and under different conditions may be estimated.

For intelligent comparison of results in mine-working, something of the quality of rock and other conditions must be known. The rock in which the above work was done is a highly indurated and, in general, comparatively seamless andesitic breccia, hardness 6 to 7, specific gravity 2.4 to 2.7. Eight hours is a day's work for every miner in the Cripple Creek district. Machine-men receive \$4, other miners \$3 per day.

American Transcontinental Lines.

Discussion of the Paper of Dr. James Douglas, New York City. (See p. 782.)

WILLIAM P. BLAKE, Tucson, Ariz. (communication to the Secretary): As one who in youth, now nearly half a century ago, had the privilege of participating in the initial explorations which have already resulted, within a single lifetime, in the establishment and development of a vast continental empire, so well described by Dr. Douglas, I may be permitted to supplement with some additional details the comprehensive sketch given in his paper.

Before the War Department, in 1853, sent out the Pacific railroad exploring parties, Fremont had already made his memorable expeditions, exploring the Great Basin and the passes into California; Sitgreaves had traversed, from east to west, the Zuni and Moqui country; and, still later, Emory had examined the region along the boundary-line between the United States and Mexico. The services of these pioneers deserve to be mentioned in even an outline of the history of continental development.

Concerning the five practicable railroad-routes, suggested in the "Reports of Explorations and Surveys," etc., as published

by the War Department when Jefferson Davis was Secretary of War, the following particulars, additional to those given by Dr. Douglas, may be of interest.

The route through Oregon, along and near the 47th parallel of north latitude, which was surveyed by an expedition under the command of Gov. I. I. Stevens, and described in Vol. I. of the quarto "Pacific Railroad Reports," was afterwards approximately followed, in part by the Northern Pacific, and in part by the Great Northern, railroad.

The central route, up the Platte, the South Platte, and the upper Arkansas, following nearly the 39th parallel south of Salt Lake, and into California by the pass named for Lieut. Beckwith (second in command), was followed by the party of Capt. Gunnison, who, as Dr. Douglas narrates, lost his life in the course of the work.

The 35th parallel route, up the Canadian river to New Mexico, across the Rio Grande at Albuquerque, westward along the Colorado Chiquito, across the Colorado near the Needles, and into California by the Mohave and the old Santa Fé trail to San Bernardino, is described in Vol. III. of the "Pacific Railroad Reports." This expedition was under the command of Lieut. A. W. Whipple and Lieut. J. C. Ives of the U. S. Topographical Engineers. The late Jules Marcou was the geologist of the party.

A party under Lieut. R. S. Williamson, U. S. Topographical Engineers, with Lieut. J. G. Parke second in command, was organized to explore routes in California connecting with the several expeditions, and to ascertain the best passes through the Sierra Nevada. The writer was geologist and mineralogist of this party, and accompanied it from Benicia to Yuma at the junction of the Gila with the Colorado, and to San Diego on the Pacific coast—including the examination of all the passes through the Sierra, into central and southern California. The reports of these surveys will be found in Vol. V.

On the arrival of Lieut. Williamson's party at San Diego, and the completion of its field-work, another party was organized by the direction of Jefferson Davis, Secretary of War, and placed under Lieut. Parke and Capt. Stoneman, with instructions to make a reconnoissance across the continent from San Diego to Galveston, on the Gulf of Mexico. This line traversed

the region in southern Arizona purchased under the Gadsden treaty, and became substantially, as Dr. Douglas observes, the route of the Southern Pacific.

Other reconnoissances were made in the Coast range of California, as supplementary to the main transcontinental surveys; and a year or two later, appropriations were granted for wagon-road surveys in Oregon, New Mexico and Arizona.

The importance of securing water along one of the routes in Texas received the attention of the War Department; and Capt. John Pope was sent out to bore experimental wells on the Llano Estacado, and especially in the valley of the Pecos, in Texas.

J. D. Robertson, New York City (communication to the Secretary): Dr. Douglas's language (page 790) concerning the Denver and Rio Grande railroad might give the impression that this is still a narrow-gauge line, not only as to the Marshall Pass division (from Salida to Grand Junction) and many "tortuous branches," but also as to the Leadville division, and even the track from Pueblo to Salida. In fact, one might infer from the passage cited, and from a further allusion on p. 797, that the Denver, Rio Grande and Western railroad secures a standard-gauge connection between Denver and the Great Basin of Salt Lake only by means of the Colorado Midland.

Since Dr. Douglas is unquestionably familiar with the present situation in these respects, I presume that his omission to state it clearly is due to the circumstance, explained in his introductory paragraph, that his paper is based upon a much earlier one, in which he has made numerous modifications, "required to bring it up to date." It is very easy, in making such modifications, to overlook the effect of phrases left unchanged, or of silence concerning new developments.

Without disparagement of the value of Dr. Douglas's most interesting summary, I think he will agree with me that, in justice to the Rio Grande R.R. Co., which has always shown exceptional courage and enterprise, not only in the pioneer work of aiding the development of new mining districts, but also in the progressive improvements required by such development, it should be clearly explained that, while of the 1657 miles of track operated by this company, a large portion (including the line from Salida to Grand Junction, over the Mar-

shall pass, many branches in southern Colorado and some branches serving mountain-districts in northern Colorado) is still of narrow gauge only, the main lines are of standard gauge—largely provided with a third rail, so that they can be used also by the narrow-gauge cars coming from mining-districts in the mountains. In particular, the line from Denver to Pueblo, from Pueblo to Salida, from Salida to Leadville, and from Leadville to Glenwood Springs, is of broad gauge (largely with a third rail, as explained). From Glenwood Springs to Grand Junction, where the Rio Grande Western begins (a distance of about 88 miles), I believe the Rio Grande and the Colorado Midland use the same track. With this exception the system controlled by the former company operates an unbroken broad-gauge track from the terminus of the Rio Grande Western to Denver.

Deep Mining at the Utica Mine, Angels, California.

Discussion of the Paper of J. H. Collier, Jr., Berkeley, Cal. (See p. 835.)

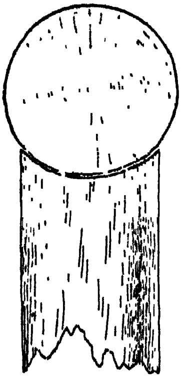
FRANK H. PROBERT, Neudorf, Anhalt, Germany (communication to the Secretary): I have read with much pleasure Mr. Collier's valuable paper. But the system of timbering which he describes as used in the levels, stopes, etc., though it must be admitted to be very strong and safe, seems to me somewhat extravagant. The amount of timber required every month for such a system must be enormous: and only where suitable material could be cheaply obtained would such a plan be economically practicable.

The first point which strikes me is the unusually great diameter of the timber employed.

In the mines of Pfaffenberg and Meiseberg, which are under my supervision, the country-rock consists of argillaceous slates, traversed by innumerable small fissures or joints, dipping at all angles and striking to all points of the compass. Undoubtedly, this net-work has been caused by the upheaval of granite masses in the vicinity. Each fissure is accompanied by a more or less well-defined gouge or flucean, caused by the rubbing together of the slates at or after the original disturbance. In such

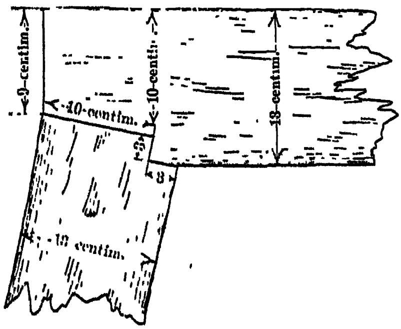
a mine the timbering must be of the very best quality and design; but we are compelled to exercise economy in this respect. It is often necessary to timber a level, both at the top and on both sides, for from 150 to 200 meters. *Thürstock* timbering, supplemented by poling, is our general method. The posts are either round or rectangular, and seldom more than 20 to 25 centimeters in diameter. The foot of each post is set firmly into the floor of the level, or, when no sound footing is obtainable, sills are used. The caps are also either round or square, and of about the same diameter. When the roof alone needs support, we simply cut a shallow curved notch in the top of the post to take the shape of the cap (see Fig. 1);

FIG. 1.



Post and Cap to Support Roof Only.

FIG. 2.



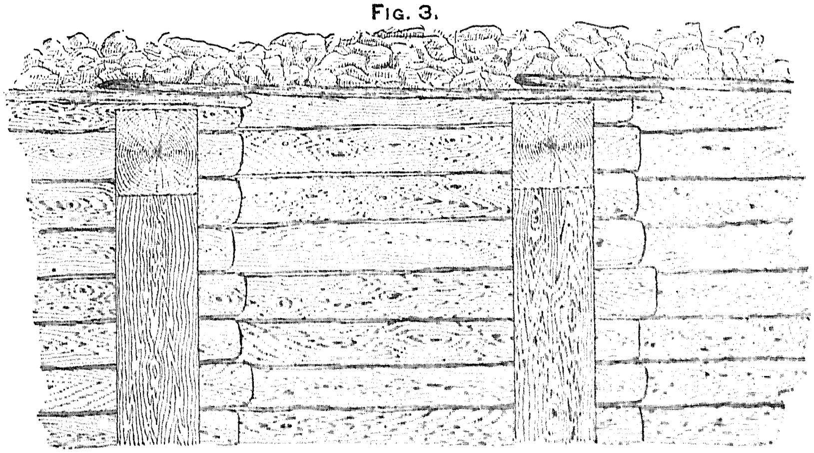
Post and Cap to Support both Roof and Side.

but when both the roof and sides of the level are insecure, we cut the timber as shown in Fig. 2. This part of the work is all done underground. The posts and caps, having been sawn on the surface into the previously measured lengths, are then sent to the working-place, and the timbermen, kept exclusively for this work, cut the notches and fit them together. Such men are paid at the rate of 2.50 marks (about 62 cents) per shift of 10 hours, or, whenever practicable, by contract, according to work done.

In very loose ground, poling is resorted to. Here again I am compelled to think that the poles used at the Utica mine are unnecessarily bulky. Our poles rarely exceed 2 meters in length and from 15 to 18 centimeters in diameter. They are

made of pine, which is found to be very good for the purpose. When we encounter running ground, posts and caps are set up about 1 meter apart, and the whole ground is made secure in the manner described by Mr. Collier; the only difference being that we use oak laths instead of poles. These laths are from 10 to 15 centimeters wide, 4 to 5 thick and 80 to 120 long. One end is sharpened, to allow it to be more easily driven into its place by blows from a hammer. The man who superintends the hydraulic pumps makes such laths in his spare time, at a fixed price a hundred. This system of timbering is shown in Fig. 3.

FIG. 3.



Poling with Oak Laths.

It is calculated that each running meter costs 15.70 marks (about $3.90), as follows:

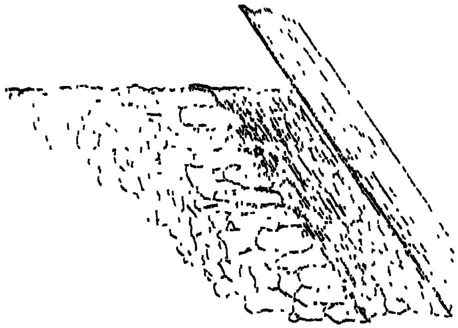
	Marks.
Timber, 13 centimeters wide, 16 broad and 5 meters long, cut into lengths of 2.2 and 1 meter, ...	4.00
Wages for cutting this from the rough by hand-saws, .	.70
Poles (75 pieces required for every meter of level), .	4.00
Wages for cutting these poles, ...	2.00
Wages of two timbermen, ...	5.00
	15.70

For the permanent timbering of levels, oak is used wherever possible. It lasts from ten to fifteen years, whereas pine lasts only four or five years; so that, in the long run, oak is more economical. It is found, however, that where there is much

water, pine is better. For the temporary timbering of stopes, pine is almost always used.

In the stopes, I am of the opinion that much more could be done with the "deads" than is set forth in Mr. Collier's paper. If I understand his account, it implies that a great quantity of such material is obtainable from the driving of levels and the development of the ore-bodies. Here in the lower Harz mountains we make use of these "deads" in many ways. Instead of using timber to make ore-chutes and man-ways, we employ two men to select the largest and best pieces of waste-rock, and to build with these, to the required height, as the stope is raised, the necessary chutes. (See Fig. 4.) These men are

FIG. 4.



Construction of Chutes with Waste Rock.

paid 1.30 marks (about 33 cents) per square meter of walling. The chutes require practically no repairs, and are absolutely solid if properly built. No cement of any sort is used.

Again, the miners themselves have to sort all the rock and put the ore into the chutes. The "deads" are stacked up in the form of a wall to support any loose ground, the fine stuff being used to make a good floor for the stope. Should a mass of rock become loose, it is immediately secured by the miners with a post and cap, until it can be supported by deads, when the post is withdrawn, so that practically no timber is lost. As the stopes are worked out the space below is filled with deads. We find this much cheaper than putting in square sets, and then filling in with deads.

The Bryan Mill as a Crusher and Amalgamator Compared with the Stamp Battery.

Discussion of the Paper of E. A. H. Tays, San José de Gracia, Sinaloa, Mexico. (See p. 776.)

A. H. P. WYNNE, San José de Gracia, Sinaloa, Mex. (communication to the Secretary): In the comparative tests reported by Mr. Tays, the stamp-batteries were provided with various styles and mesh-sizes of screens, while the Bryan mill was run throughout with a slot-punched Russia iron, equivalent to a 30-mesh wire screen. This is a somewhat one-sided method of comparison. Should not the Bryan mill also have had the chance to show what it could do with other screens?

I cannot wholly approve Mr. Tays's proposed improvements upon the Bryan mill. In my judgment, the inventor has given us a machine well-adapted to the work for which it was designed, namely, the crushing and amalgamation of soft ores.

In my judgment, the principal cause of failure to amalgamate satisfactorily in the Bryan mill is not, as Mr. Tays thinks, the shallowness of the basin, or the lack of copper plate about the inside periphery of the mill, but rather the want of experience and practical knowledge on the part of most amalgamators. Having had experience, not with one Bryan mill only, but with several, and taking into consideration the experience of other capable mill-men, I am positive that the proper way to save gold in this mill is: first, to use enough quicksilver to keep the amalgam liquid, thus allowing it to accumulate in the annular space between the dies and the rims of the basin; secondly, to replace the old dies, when a little more than half worn-out, with new ones; and, thirdly, to clean up the mill at least every two weeks—or oftener, if rich ore is being treated.

It is evident that Mr. Tays endeavored to amalgamate quite "hard," as is done in a stamp-battery, in which case the swash of the pulp would scour off portions of the hard amalgam adhering to the inside plates and dash it through the screens—after which a considerable amount would be lost through floating on, or in, the pulp in its journey over the outside plates, and

not coming into contact with the latter. Had Mr. Tays employed the method outlined above, I think he would have saved inside the mill much more than 33 per cent. of the gold—80 per cent. would be nearer the mark.

Mr. Tays pronounces (p. 781) the Bryan mill to be, as an amalgamator, the equal of the stamp-battery, especially with soft free-milling ores (the identical variety treated in his experiments), while he reports (p. 780) that 65 per cent. of the gold was saved in the battery-mortars, and only 33 per cent. inside the Bryan mill. His tables show that while the total extraction by each apparatus was about the same, a much larger proportion was secured on the outside plates in the case of the Bryan mill. But these plates are an addition to both the battery and the mill, and no intrinsic part of either. Whatever gold is caught on outside plates should not be taken into account in comparing the amalgamating-efficiency of the machines proper. On the other hand, as already explained, much of the amalgam caught on the outside plates of the Bryan mill was unnecessarily dashed out of the mill by an unsuitable method of operation. The total yield would have been differently divided between inside and outside, if the amalgamation had been properly conducted.

Whether a 4-foot Bryan mill crushes, as Mr. Tays says (p. 781), as much ore as two 5-stamp batteries, depends wholly on the kind of ore. Its relative efficiency would be as high as that, with fairly soft and very clayey ore; because the violent centrifugal motion of the pulp in the Bryan mill diminishes the clogging of screens by clay, which seriously hinders the discharge of a stamp-battery. But if the ore be quartz, and not reduced in the rock-breaker to less than an inch in diameter, the output of a 4-foot Bryan mill will not exceed that of a stamp-battery.

Mr. Tays found, in experimenting with the battery, that a punched-tin screen discharged more crushed ore than a wire-gauze screen of equivalent mesh. He does not state, however, whether the wire was thick or thin, iron, steel or brass. If the screens were of thick iron wire, and rusty at the same time (as was probably the case), the assertion might be correct. Otherwise it is not so. As a punched-tin screen has much more blank surface than, say, a thin brass-wire screen, and is, at the same time, thicker, it cannot discharge more crushed ore than the latter.

Unless the above qualifications are borne in mind, readers of Mr. Tays's paper, notwithstanding the useful information which it contains, may be misled by its general conclusions.

Refining by Converter at the Copper Queen Works, Arizona.

Discussion of the Paper of Dr. Douglas, New York City. (See p. 511.)

EDWARD KELLER, Baltimore, Md. (communication to the Secretary): When, at the New York meeting, February, 1899, Mr. Douglas gave an abstract of his highly interesting paper on the Copper Queen mine, he invited the members of the Institute, in his usual progressive spirit, to make a full scientific investigation of the region of that mine during the prospective excursion to Bisbee, Arizona. I volunteered to examine some of the metallurgical processes and products of the works, and obtained from Mr. Douglas a valuable series of samples. Upon the issue of his paper, however, I found that he had already a considerable volume of analyses of those products, and that little was left for me to do in that respect, except to duplicate his results, the importance of which work would not have been commensurate to the time and labor involved. I selected, therefore, only some points which he had not made entirely clear, or concerning which I was skeptical. The details of most of my work will appear in a future paper.

From Mr. Douglas's figures I have calculated the values for the elimination of impurities in the so-called Leghorn converter, introduced by him at the Copper Queen works, and have found them to be as follows:

Percentage of Elimination of Impurities in Four Blows of a Converter.

No. of Blow.	Sulph'r	Iron.	Zinc.	Nickel.	Lead.	Antimony	Arsenic.	Selenium and Tellurium
1..........	99.4	99.6	88.0	92.6	94.4	81.6	83.8	40.3
2..........	99.0	99.6	98.1	92.5	96.8	71.9	76.6	38.1
3..........	98.8	99.5	93.5	91.4	96.3	63.8	80.6	25.3
4..........	99.8	99.5	95.8	95.8	97.5	65.3	76.9	36.3
Average	99.2	99.6	93.8	93.1	96.2	70.6	79.5	35.0

Those elements for which I have determined the elimination in other converters, and which also appear in the above table, are lead, antimony, arsenic, selenium and tellurium. Mr. Douglas's results as to these show no new feature; they closely corroborate my own, as given in a former paper.* Selenium and tellurium, in Mr. Douglas's case, as well as in my own heretofore, were determined jointly. As the Copper Queen mattes contain a greater amount of both elements than the mattes which I had previously analyzed, I now took occasion to separate the two, and found the elimination of selenium to be somewhat greater than that of tellurium. To sulphur, iron and zinc I paid no attention in my former publications, because I always considered them as members of a group of elements of which 99 per cent. or more is eliminated in the converter. In fact, I have been unable to find zinc in the copper of the Copper Queen or in any other converter-copper.

Mr. Douglas gives to nickel as high a figure for elimination as to zinc. Since zinc is a far more oxidizable and volatile metal than nickel, I thought there was good reason to doubt the correctness of this conclusion. In the course of analysis, unless a separation of nickel and cobalt be attempted, the two elements would naturally be determined together. In the Copper Queen mattes I found that, of the sum of the two metals, from one-fourth to one-half is cobalt; and as the latter (being practically all eliminated in the converter-process) could not be found in the copper, I found the elimination of nickel to be much below Mr. Douglas's figure. The cobalt, on the other hand, must now be placed in the same category as sulphur, iron and zinc.

I subjoin an analysis of a Copper Queen matte as being, perhaps, of some mineralogical interest. The figures are not derived from one sample, but culled from half a dozen:

Composition of Copper Queen Matte.

	Cu.	S.	Fe.	Zn.	Co.	Ni.	Pb.
Per cent., . .	54.89	23.36	20.25	0.34	0 024	0.0341	0.1178

	Bi.	Sb.	As.	Se.	Te.
Per cent., . . .	0.0044	0.0232	0.0171	0.0113	0.0088

	Ag.	Au.
Ozs. per ton, .	6.0	0.10

* "The Elimination of Impurities from Copper Mattes in the Reverberatory and the Converter," *Trans.*, xxviii., 127 (1898).

As compared with the mattes of Butte City, Mont. (see my paper already referred to), it will be seen that the Arizona matte is lower in gold, silver, and bismuth, but higher in selenium and tellurium. This I mention, because it is my impression that all these elements are generally supposed to be associated.

On mathematical grounds, one might expect that with increase in the capacity of a converter there would be an increased economy in the wear of the converter-lining; the surface of the matte in contact with the lining increasing at a "square" rate, while the mass of the same matte increases at a "cubic" rate. In the case of Mr. Douglas's slags, their acidity, in fact, decreases in each succeeding blow, as will be seen by his figures:

Acidity of Converter Slags.

	First Pouring. Per Cent. Silica.	Second Pouring. Per Cent. Silica.
First Blow,	36.78	34.61
Second Blow,	35.30	33.46
Third Blow,	34.35	32.60
Fourth Blow,	32.57	

Mr. Douglas does not give the weight of the matte charged or of the copper produced. Only the number of copper bars are given, as follows:

	First Blow.	Second Blow.	Third Blow.	Fourth Blow.
No. of Copper Bars,	9.5	14.5	14.5	12

It may be assumed that the weight of matte or copper was proportional to the number of copper bars; in which case there was no regular increase in the capacity of the converter. The mathematical theory, therefore, does not apply in this case. Perhaps the real reason for the reduced acidity of the slags in successive blows is found merely in the physical condition of the lining, which may have become more and more compact by continued heating.

INDEX.

[NOTE.—In this Index the names of authors are printed in small capitals, and the titles of papers in italics. Casual references, giving but little information, are usually indicated by bracketed page-numbers.]

ERRATA.

1. In Vol. xxviii., page 895, line 20, "antimony" should be "tin."

2. A list of errata in Mr. Scott's paper on "The Evolution of Mine-Surveying Instruments (Vol xxviii., 679) will be found on page 931 of this volume.

3. In this volume, on page xxxviii, the title "Notes on the Operation of a Light Mineral Railway," etc., is erroneously included among the papers of the New York meeting. This paper was read at the Buffalo meeting, September, 1898, and is printed in Vol. xxviii., page 600.

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